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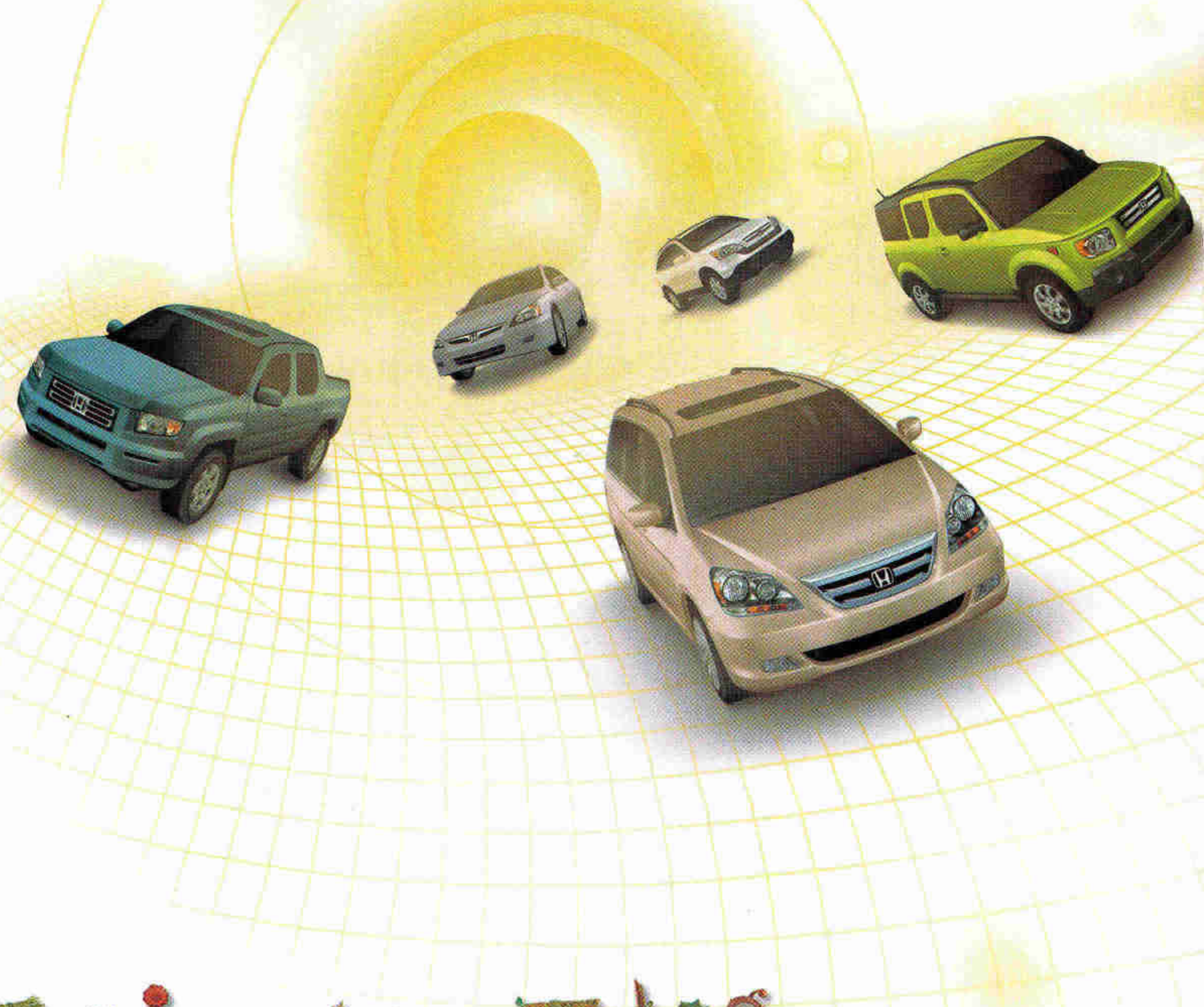
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The most fuel-efficient auto



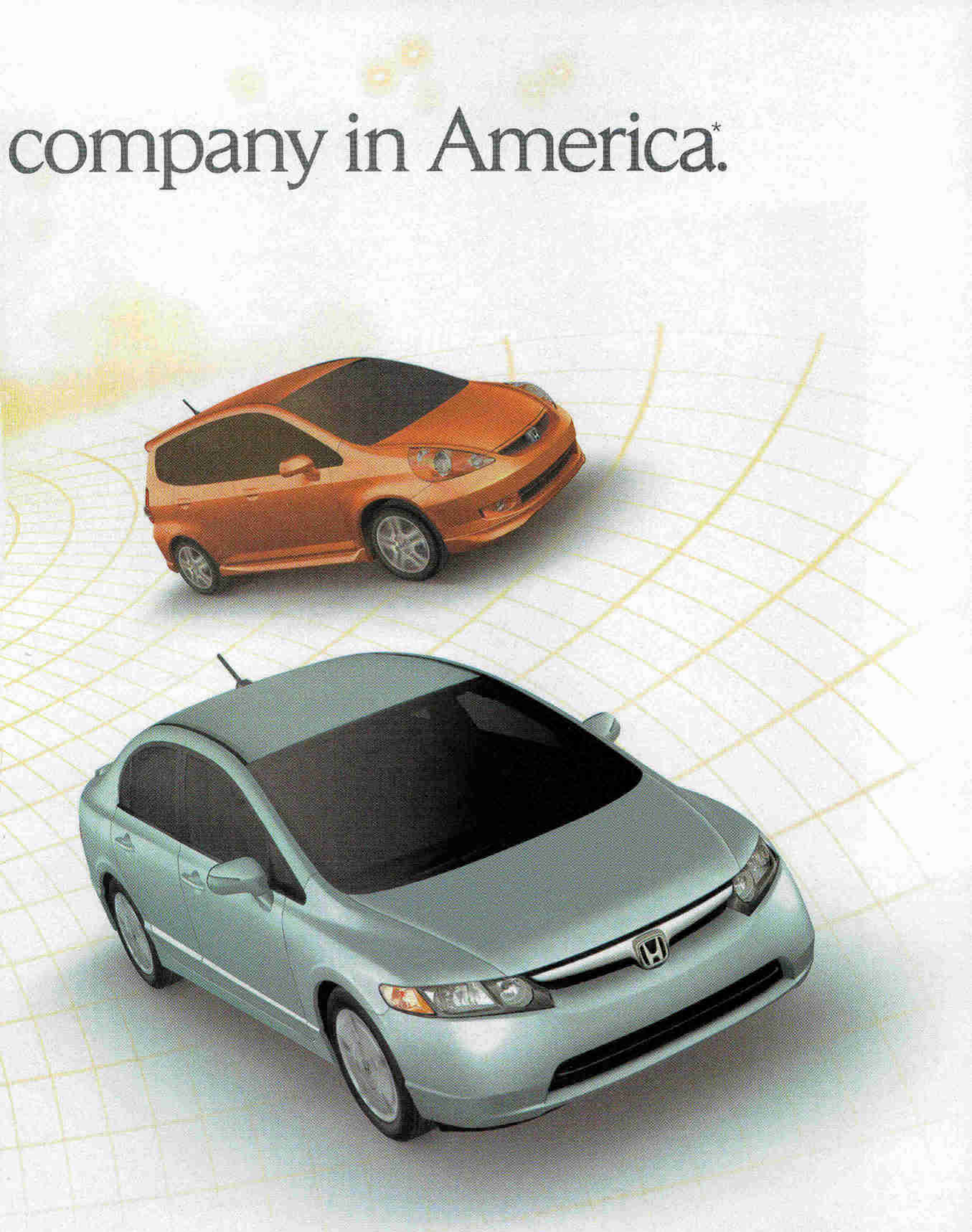
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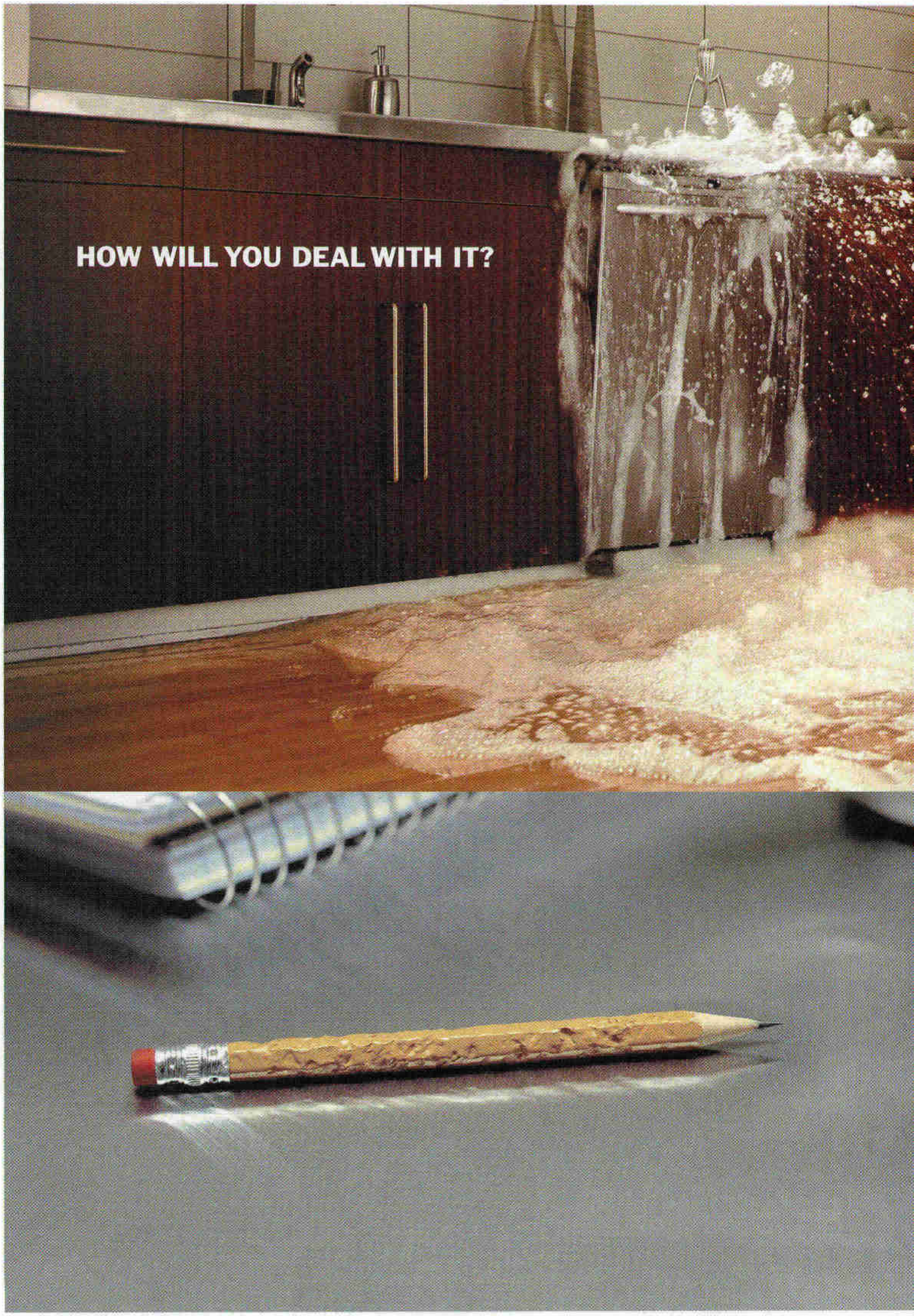
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If Carlos knows he is half Irish, one quarter Spanish, and one quarter Chinese, how is it possible that he is also 100% Tanzanian?*

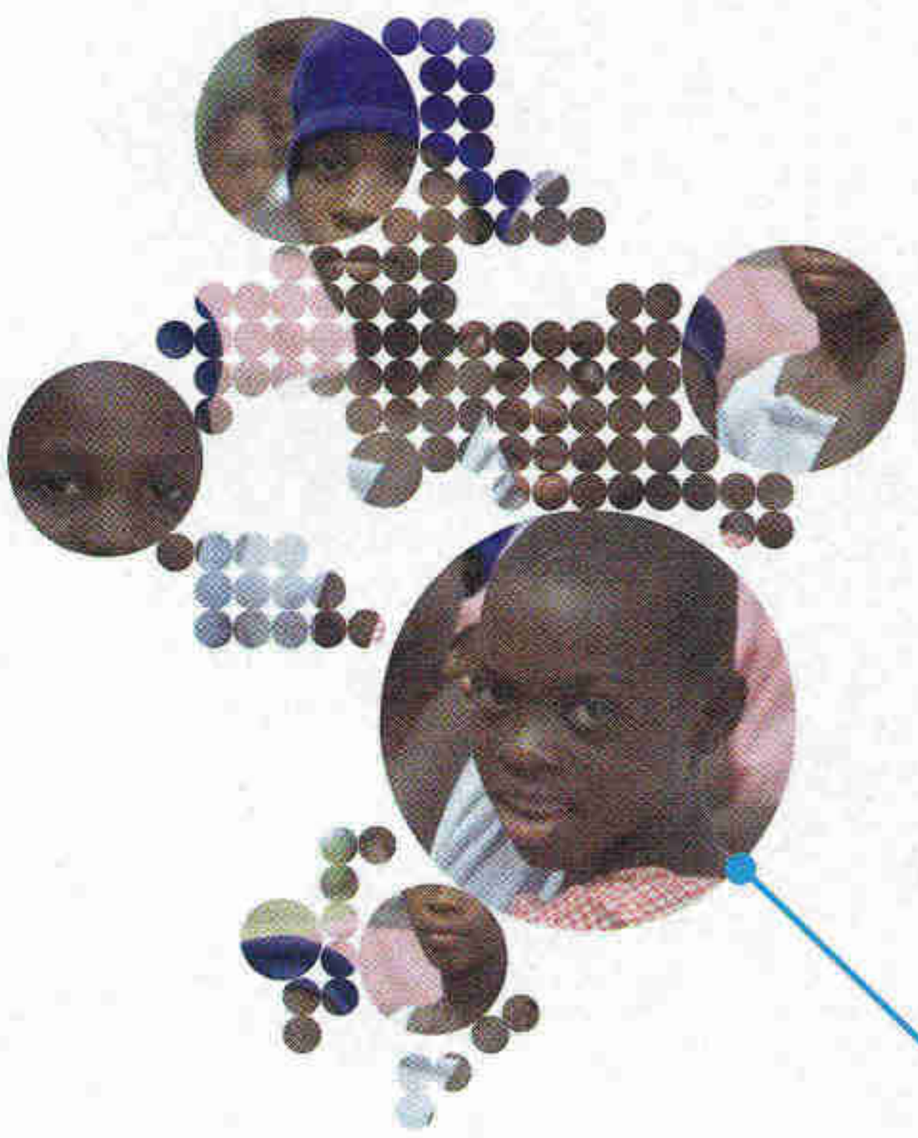
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NATIONAL GEOGRAPHIC

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They met on the Internet, and they were wed on Mendenhall Glacier in Alaska's Tongass National Forest. Story on page 102.



MELISSA FARLOW

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The rapidly spreading disease affects more people than ever before. But until recently, the outcry has been muted.
BY MICHAEL FINKEL PHOTOGRAPHS BY JOHN STANMEYER

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The Genius of Swarms 126
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BY PETER MILLER

COVER Malaria carrier, a live *Anopheles stephensi* mosquito looms large in a color-synthesizing scanning electron microscope.
PHOTO BY DAVID SCHARF

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Spy on an Eagle
Watch bald eagles flying from their nest on the coast of Maine. Our latest WildCam is at ngm.com/eaglecam.

Impressions of Malaria
Photographer John Stanmeyer shares his thoughts about documenting the deadly disease.

Keeping Up With the Climate
The latest reports from *Climate Connections,* a collaboration between National Geographic and NPR, are posted at ngm.com/climateconnections and npr.org/climateconnections.

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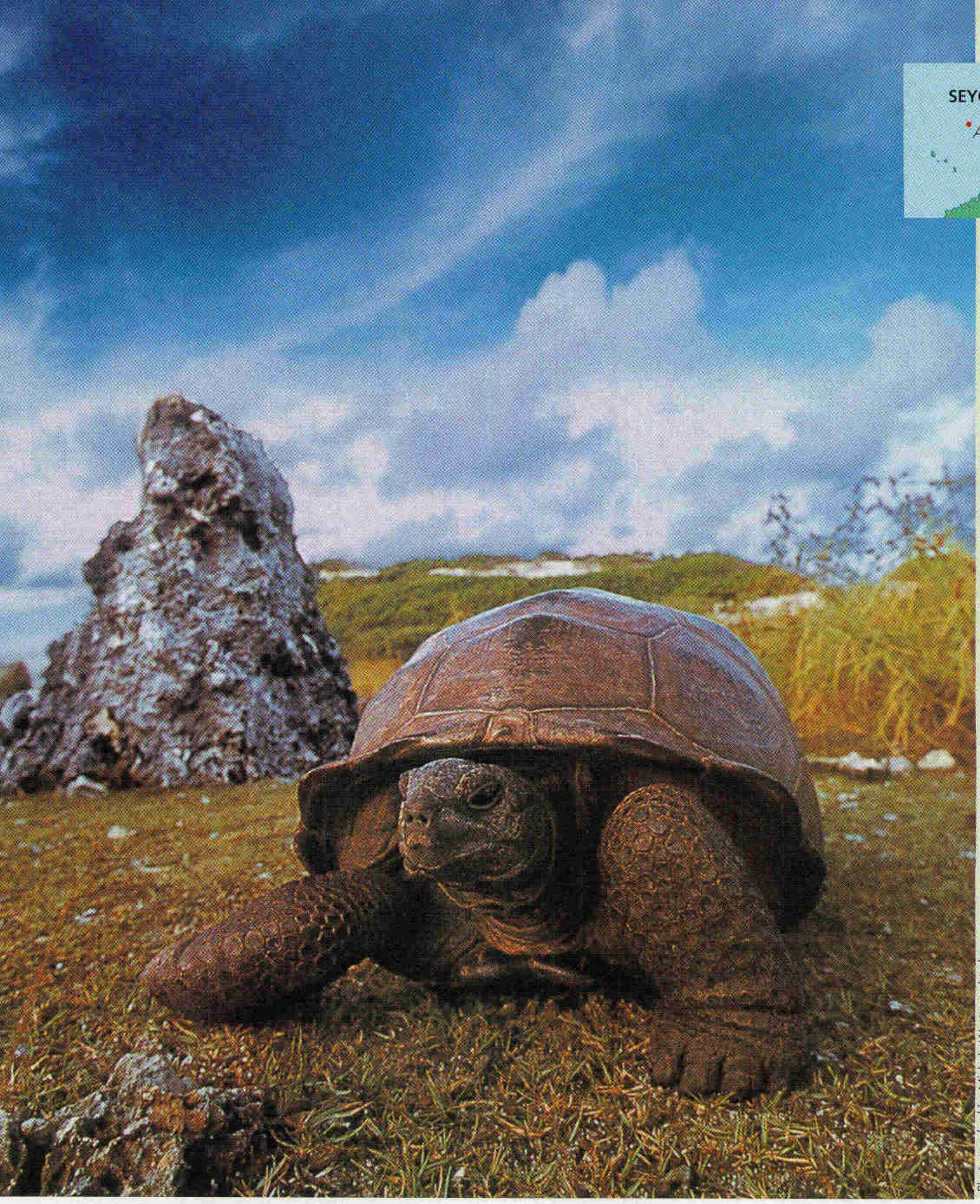
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PHOTOS (LEFT TO RIGHT): PABLO CORRAL VEGA; WORLD PARROT TRUST; PAUL GILHAM, GETTY IMAGES



Aldabra Giant Tortoise
(Geochelone gigantea)

Size: Head and body length, 35 - 47 inches

Weight: 330 - 551 lbs

Habitat: Primary habitat is a low-lying coral atoll whose flat, rocky terrain includes mixed scrub and shrubs

Surviving number: Estimated at 100,000 - 150,000

Photographed by Michele Westmoreland

WILDLIFE AS CANON SEES IT

Change takes a toll even on an atoll. The Aldabra giant tortoise has been lucky in its locale — a raised coral atoll whose extreme isolation helped a handful of tortoises escape the mass harvesting that persisted to the end of the 19th century. There, life went on, with females laying several new clutches — each holding up to 25 eggs — per year. But the young, who face the world immediately after hatching without the benefit of parental care, still find survival a challenge. Competition with introduced species, climatic fluctuations and a limited habitat show that life can be tough even in the best of locations.

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EDITOR'S NOTE

It began suddenly, just before lunch, as our Land Rover bounced over a dirt track on a dusty plain in Tanzania. Fatigue, I thought, or maybe the heat. Maybe I just needed to stop, stretch, and eat. But lunch provided no relief. My stomach was in knots.

I climbed back into the vehicle. Soon my churning stomach became the least of my concerns. My head hurt so badly I thought it would explode. My vision blurred. My body ached as if I'd been trampled by a rhino.

In late afternoon, I rolled out of the Land Rover and lay on the ground, helplessly inert. One instant my body was on fire, the next I was freezing. Shivering uncontrollably, I curled up in the dirt and drifted off into a fog. "Looks like he's got malaria," I heard my guide say, somewhere in the distance.



Anopheles mosquitoes transmit malaria.

"I've got a medicine kit," I mumbled. He rooted around in a metal box, found a bottle of tetracycline, and fed me a megadose. Then he gave me Fansidar, a potent drug. I swallowed the pills, not caring what they were, hoping I could keep them down.

The fever broke at two in the morning. Less than three hours later, I slowly began to climb the Maasai's sacred 10,000-foot volcano, Ol Doinyo Lengai. I felt drained, dehydrated—and glad to be alive. But how to explain the malaria? Though I'd been taking chloroquine and Paludrine, two antimalarial drugs, for months, my defense was, literally, full of holes. A few weeks earlier, I'd discovered several tears in my mosquito net. I was working in an area in Kenya known for a virulent strain of malaria and assumed the drugs would protect me. But the mosquito that infected me carried parasites that had developed resistance to those drugs. They were useless.

I was fortunate. I survived. Many do not. Malaria kills 3,000 African children every day. That's more than a million lives a year. This month's cover story takes us to the front lines of the battle against one of the world's deadliest, most costly, diseases.

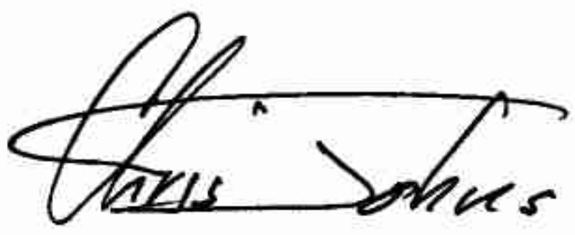


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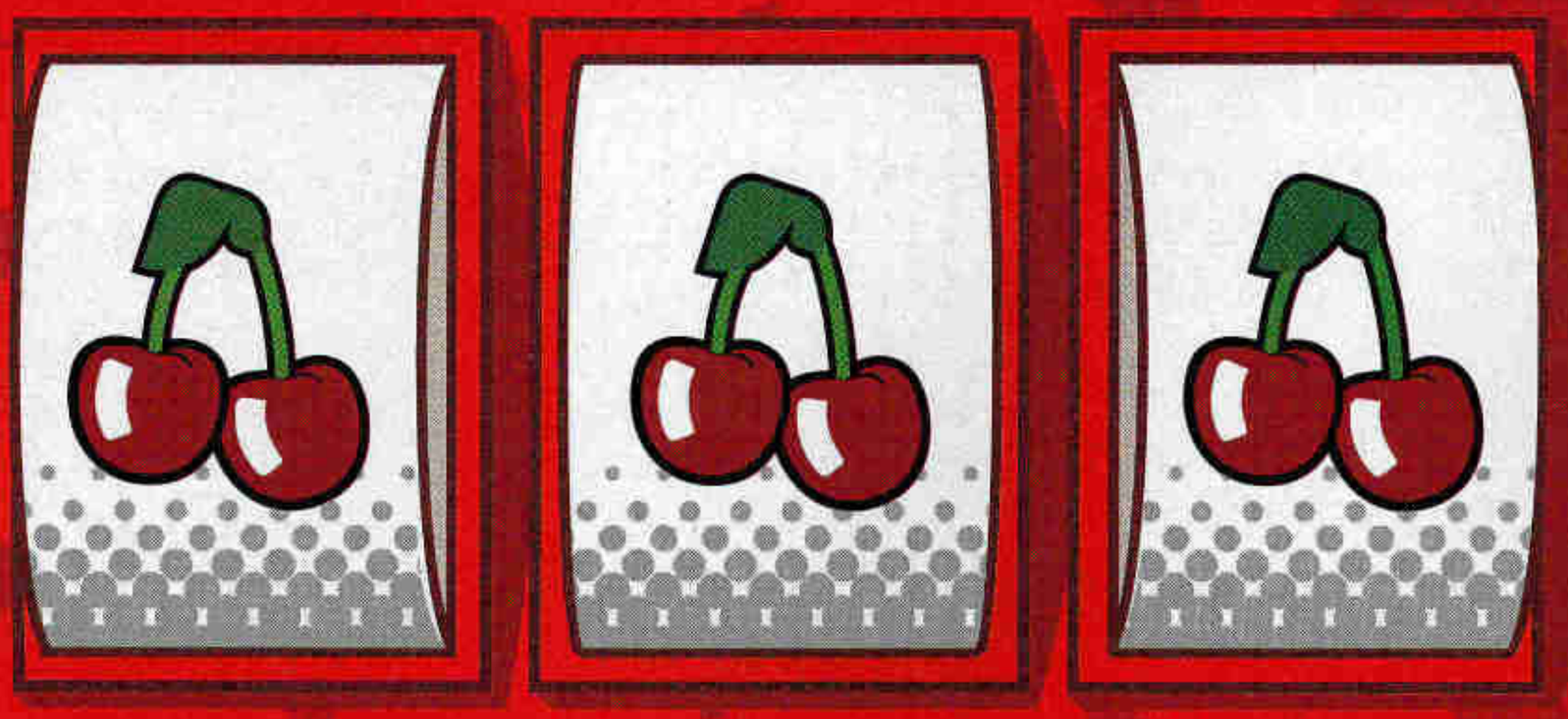
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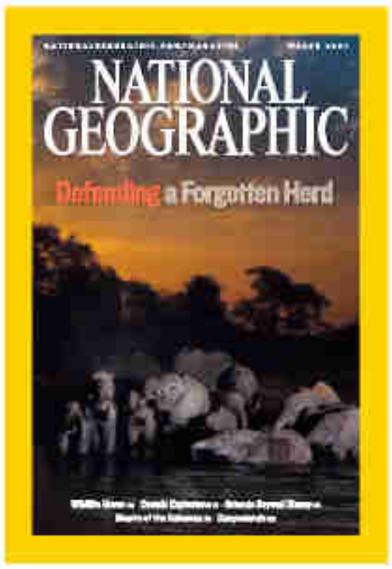


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LETTERS



March 2007 *Our stories on elephants and Orlando accounted for the most letters, but one reader questioned a statement in "Shark Eden" that sharks bite fewer people each year than New Yorkers do. "Since when do New Yorkers bite?" wrote Rose Motyczka of Roselle Park, New Jersey. In 2005, 237 people were treated for human bites in the city's hospitals.*

Voice opinions about July stories at **ngm.com.**

Ivory Wars

I almost didn't read this article because I knew—based on the cover and a few accidental glimpses of the graphic pictures within—it would leave me heartbroken and disgusted. I've often asked myself when I see similar stories in NATIONAL GEOGRAPHIC, why you think anyone would want to read them. I must commend you, however, on the power of this article. You've exposed a horrendously inhumane and chilling problem. I wept for the animals killed so savagely and so callously (and for their offspring), but I also felt inspired that such brave people are working to stop the poachers.

TONY REED
Albuquerque, New Mexico

Reading about the brave attempts at keeping the elephant herd of Zakouma alive is at once encouraging and heartbreaking. Encouraging in that there are still many people who believe that wildlife in Africa is their heritage and is worth protecting and conserving for generations to come. Heartbreaking in that the exploitation of this heritage by the insatiable markets of China and East Asia will probably ensure that future generations in Chad will never see their elephant herds in the flesh.

G. DAVIDSON
Harare, Zimbabwe

It took me four days to get through "Ivory Wars." I'm not normally someone who gets overly emotional, but I was wrecked by that article. In those few pages I traveled from information to astonishment to anger and on to rage. Eventually I hope to be able to use what was presented for some positive action somewhere, but for now I can't, and I don't want to go back and look. I know that story needed to be told, but give me warning next time.

GARY SMYTH
McMurray, Pennsylvania

I wonder if J. Michael Fay has put much thought into why poachers are killing these elephants. Rather than simply being cruel aggressors who are killing "at the expense of their souls," these poachers are clearly attempting to conserve another species: themselves. We should not be at all surprised by, nor always condemn, otherwise destructive measures taken by desperate humans to ensure their own survival.

GREG PUGLIESE
Sunnyvale, California

I was shocked and utterly horrified to see the photograph of the elephant with its face chopped off. How or why would you wish to display such a horrific scene in your magazine? I also objected to the description of the removal of an elephant's tusks. Have you nothing better to do than display man's inhumanity to the animal kingdom?

ELSIE S. DAWSON
Salt Lake City, Utah

I had no idea how much these majestic animals were suffering. I always knew they were hunted and killed for their tusks, but the photograph of the elephant with its face literally cut off nearly brought me to tears. The wording and imagery made me almost believe I was there.

MARISSA HENRIKSON
St. Petersburg, Florida

The valiant and humane rangers, guards, and conservationists who risk their lives to protect elephants, rhinos, gorillas, and all African wildlife species personify compassion in action. The ruthless poachers who kill endangered species and their human protectors are rife with violence and irreverence for life.

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LETTERS

Orlando

As president of a company that operates two of the theme parks author T. D. Allman found so objectionable in his article on Orlando, I feel compelled to offer another view. His article manages to do something I would have thought impossible: find fault with a community that provides wholesome family entertainment and educational experiences for millions of visitors while providing many jobs. Allman is particularly critical of SeaWorld, a park that with its sharks detaches "experience from context." I submit that if there were ever an animal for which detaching experience from context was prudent, it is the shark. But in addition to learning about sharks in safety, visitors to Orlando can touch a sloth at Discovery Cove without traveling to Bolivia. They can see a beluga whale at SeaWorld without sailing into Canada's Resolute Bay. And they can experience an endangered leatherback sea turtle without diving a thousand feet beneath the surface of the Pacific Ocean. These opportunities might explain why nearly six million people will visit SeaWorld and Discovery Cove this year alone. I should also note that contrary to Allman's assertion, we do not "pluck" whales from the ocean. In fact, SeaWorld has not collected a killer whale from the wild since the mid-1970s. The most recent of the hundreds of whales and dolphins born in our parks was a killer whale calf born March 12 at SeaWorld Orlando. And finally, I was left to consider what Allman would have said about Orlando had NATIONAL GEOGRAPHIC truly sought to "inspire people to care about the planet." Perhaps he would have written about children who have learned to appreciate wildlife and environmental conservation in places like SeaWorld, Busch Gardens, Discovery Cove, and Disney's Animal Kingdom. Or maybe he would have focused on people like Mohammed Kamal, an immigrant from Bangladesh who came to Orlando in 1997 seeking a better life for himself and his family. Today Mr. Kamal owns a home and works as a training supervisor at SeaWorld. Perhaps your readers would have found his story as inspiring as I do.

KEITH M. KASEN
Busch Entertainment Corporation
Clayton, Missouri

I frequently travel to Orlando as part of my work and enjoyed your coverage of the non-Disney aspects of the city. The Central Florida Research Park near the University of Central Florida matches your description perfectly. The area around this high-tech Silicon Swamp offers a wide range of hotel accommodations, eateries, strip malls (some quite upscale), and just about everything else a business traveler might need. In other words, it is the perfect place not to call home.

JAY BRAUN
Los Angeles, California

Corrections, Clarifications

March 2007: Orlando Children from nearly 200 countries attend all schools—not just two—in the Orange County school district.

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LIFE TAKES VISA

Things to do while you're alive:

- ☐ See a Broadway show, front-row center
- ☐ Celebrate Carnival in Rio
- ☐ Drink a mint julep at the Kentucky Derby
- ☐ Build a house
- ☐ Perfect a foreign accent
- ☐ Attempt to break a world record
- ☐ Invent something
- ☐ Climb Mount Everest
- ☐ Save a life
- ☐ Visit the Taj Mahal
- ☐ See the cherry blossoms in D.C.
- ☐ Complete a triathlon
- ☐ Learn to survive in the wilderness
- ☐ Stand on the equator
- ☐ Ride a boat through a fjord
- ☐ Visit all 50 states
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LETTERS

As a child, I enjoyed oranges from my uncle's grove near Orlando. But after a few bad years and poor harvests, he, like many people in the area, sold out to the developers. In 1996, after I left Michigan to live in England with my British husband, someone asked why I would ever want to leave America to live in England. When I asked if they had ever been to America, the response was, "Oh yes, we've been to Disney World in Orlando, and it was amazing." I had to reply that Disney World was not America, it was all a fantasy. It sounds like the fantasy is now turning into more of a nightmare.

LINDA FORSTER
Gosport, England

A lifelong resident of a (once) small town outside Orlando, I have witnessed firsthand these changes. The overnight conversion of pastureland and orange groves is a fact of life in this newly formed metropolis. What the author did not shed light on is the weak infrastructure of this area. The population explosion has sparked an enormous rise in property taxes to build new schools and roads, and add police and fire protection. Many lifelong residents have been displaced because they cannot afford to live here anymore. The bustling low-wage service industry produces workers who cannot afford to buy a home or even rent an apartment.

DANIEL PATERSON
Clermont, Florida

Usually articles in NATIONAL GEOGRAPHIC make me want to visit the places they describe. Even the shark article made me want to swim with them in the Bahamas. But not the Orlando article. I can't remember any other article that has painted such a bleak and depressing picture of a vacation destination. Why would I want to spend hundreds or even thousands of dollars on a trip to Orlando when I can see the same housing developments, malls, megachurches, chain restaurants, traffic jams, and crime in my own hometown for only the price of a tank of gas?

KAY E. WEBB
Tulsa, Oklahoma

I wept for the animals killed so savagely and so callously (and for their offspring), but I also felt inspired that such brave people are working to stop the poachers.

I think the author had a bad childhood and was never allowed to go to Disney World and, as a result, clearly has a cynical and jealous dislike for all the things that Orlando offers. Too bad for him.

JOE BALSKUS
Portland, Connecticut

Shark Eden

Eleven years ago I was one of the sleep-deprived twenty-something volunteers at the shark lab in Bimini. There was nothing like running a longline at 2 a.m. and seeing a float was down—it usually meant that there was a shark at the other end of the line. But was it big or small, reef, lemon, or bull, tired or ready to fight? It didn't matter; they were all thrilling adventures, even with fish guts and slime in my hair from baiting the line. I spent almost a year there, and it remains one of the best experiences of my life. I am glad to see "Doc" getting the attention he deserves on a national stage. He has dedicated his life to doing something he loves. Sharks are a hugely important part of the ecosystem as top predators and deserve to be studied and protected. Perhaps one of these days I'll go back and see if my shark-tracking skills are still up to par.

KIMBERLY REUBUSH
Dumfries, Virginia

The destruction of such a perfect ecosystem containing magnificent apex predators is an outright shame. This short-term gain and long-term devastation has to stop. Only humans could find entertainment in gambling while being totally oblivious to gambling with the future of our planet.

SHANNON CURTIS
Fort Frances, Ontario

Canyonlands

You published a splendid article on our canyon country in Utah. I truly believe that the explorer John Wesley Powell would roll over in his grave to know that Glen Canyon lies underneath a lake with his name on it.

GERALD I. THOMPSON
Layton, Utah

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FACT

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LETTERS

Your Shot

I was surprised to see the Concorde flying again, only to realize it was the needlefish showing extraordinary athleticism!

GRACE AGARDY
Sunnyvale, California

Environment: Green Giant

I found the following comment in the article about the world's tallest known tree a prime example of everything wrong with the environmental movement and environmentalists: "Today, it's well-meaning tourists rather than loggers who could harm Hyperion, by compressing the soil at its base—so the tree's location is being kept a secret." In other words, a public tax-funded section of a public national park is being kept accessible to only a select few. The entire action smacks of the very elitism that justifiably gives the environmental movement a well-deserved black eye.

JOHN PANCOAST
Thief River Falls, Minnesota

Health: Forbidden Fruit

Regarding your article on grapefruit's interaction with medication: I find the implied irony of increasing intake of strong drugs and decreasing the intake of healthy foods discouraging. Note to self: Stop eating healthy foods and take more medication.

AMANDA LOUGHLIN
Kansas City, Missouri

President's Note

John Fahey mentions archaeologist Constanza Ceruti, one of the few female archaeologists doing high-mountain research. The work she has done is admirable, and being an adopted Argentine, I feel very proud of her and even more proud that she was part of the Prince of Asturias Awards ceremony. I think that by now your magazine should be called International Geographic. More than just national, you are all over the globe.

ANTOINETTE HUFFMANN
Buenos Aires, Argentina

Special Advertising Section



THE SURPRISING POWER OF CLEAN TEETH.

Could twice-a-day tooth brushing help protect more than your smile? In fact, your mouth is a vulnerable entry point for bacteria associated with many serious health conditions. So your oral health routine can play an important role in maintaining your overall health. Periodontal disease can impact your body's ability to defend itself. For example, people with severe gum disease may have a significantly greater risk of stroke or heart attack. Studies also associate poor oral health with serious conditions such as diabetes. And when severe gum disease is present, some pregnant women may be more likely to deliver a pre-term low birth weight baby. So keep brushing. Sometimes the little things can make the biggest difference of all.

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Glen Dettmer
Winter Park, Florida

Construction worker Glen Dettmer first spotted this snail and grasshopper in the weeds near his Fort Lauderdale job site. Then he photographed them on a desk in his hotel room before releasing them. "The company gave me the camera for work," admits Dettmer, 44. "It's supposed to be for shooting before-and-after pictures of construction." But South Florida's plentiful wildlife has shifted his focus. "I've shot millipedes, turtles, fish, and iguanas so far," he says. "I don't think I've used it for work yet."

★★★★★

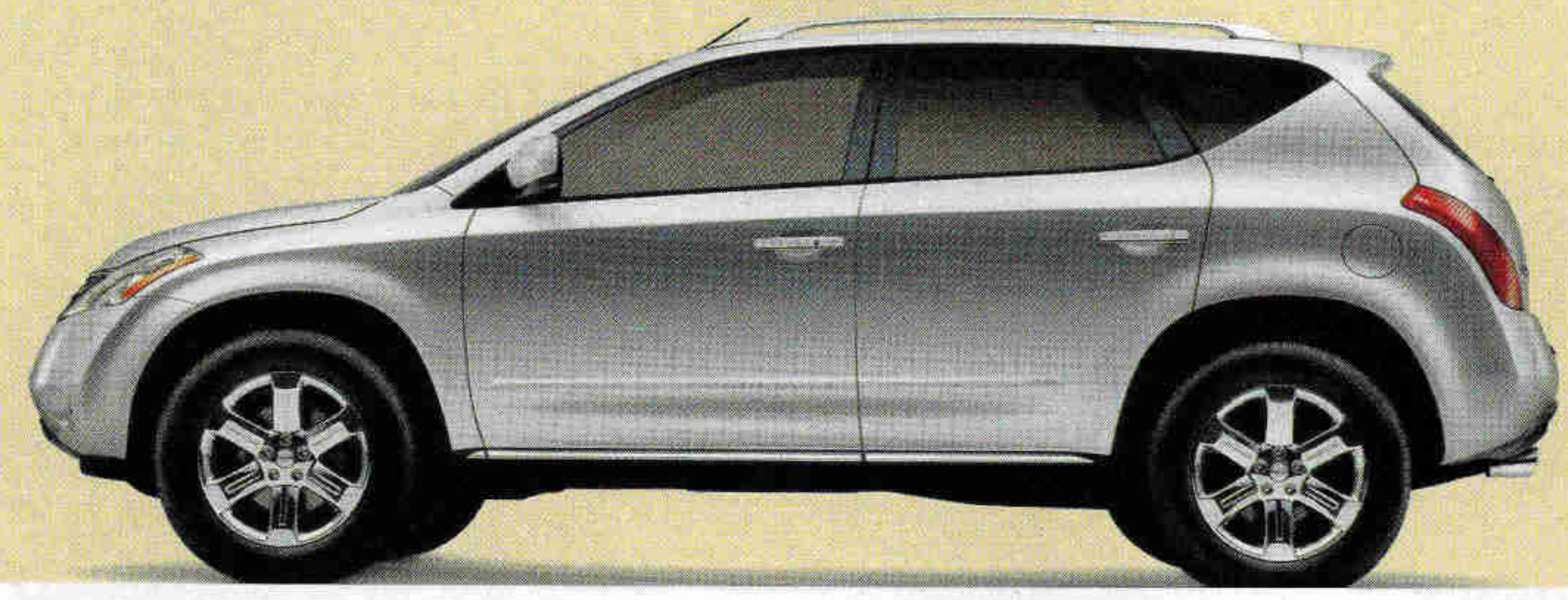
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Ski Dubai offers the desert-weary 5.5 indoor acres of manufactured snow, fake evergreens, and meat-locker cold.

A contributor to National Geographic*'s German-language edition, Austrian Reiner Riedler has published books on Ukraine and Albania.*

Imitation Destinations Travel used to mean exploring a specific location, in a specific season, having the particular experiences that were possible in that setting at that moment. But money and technology, it seems, can make geography irrelevant. Wealthy people in developed nations have become so accustomed to having whatever they want whenever they want it—watermelon in winter, Italian food in Japan—that place and time are becoming vague concepts for a lot of vacationers.

Paris creates a temporary "beach" along the Seine each summer: Truckloads of sand, potted palms, lounge chairs, and beach bars are dropped onto a riverside roadway. It's hugely popular. That started me thinking about the trend toward fantasy holidays. It's July on the Arabian Peninsula, and you're longing for a break from the desert heat. You could wait until winter and fly to the Alps for a dose of snow, but Ski Dubai (above) has five downhill runs, a snow cave, two après-ski cafés. They'll even rent you an overcoat. Just don't examine the illusion too closely, or you'll see that the starry sky overhead is a painted ceiling with electric lights.

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With the (replica) onion domes of Moscow's St. Basil's Cathedral looming ahead, and the (re-created) facade of a medieval sultan's palace off to the left, no one even turns a head to watch Superman jumping into a swimming pool at the World of Wonders resort near Antalya, Turkey. Visitors do become part of the show when they buy a gondola ride on an indoor miniature of Venice's Grand Canal in Las Vegas. The original flows past masterworks of Renaissance architecture. At the Venetian hotel, you can float by Banana Republic and the food court.



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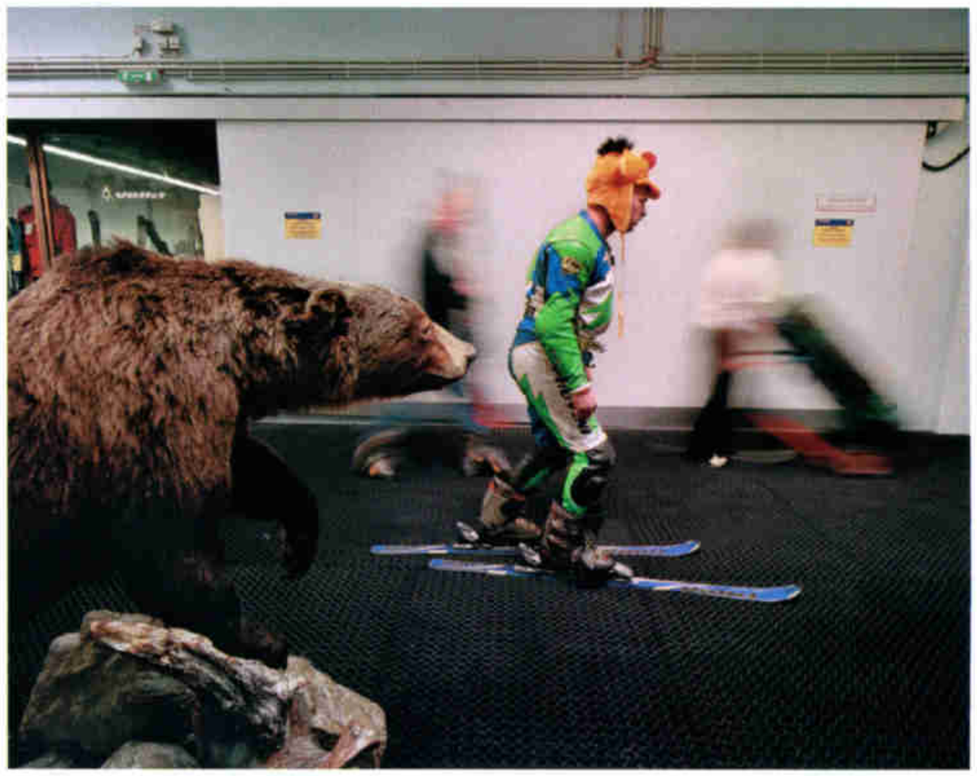
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"I try to look for the intersections," photographer Reiner Riedler says, "places where the reality of the surroundings and the illusions of the artificial worlds collide." Ringed by asphalt and streetlights, a tyrannosaur rears up in mid-roar at Dubailand (above), a hundred-square-mile, multibillion-dollar theme park complex under construction in the United Arab Emirates. At a 67-million-dollar ski hall in Germany, a bear stands forever on one forepaw as winter sports enthusiasts make their way from the gear shop to slopes coated year-round in snow.



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IMPORTANT SAFETY INFORMATION: Lunesta works quickly, and should be taken right before bed. Be sure you have at least eight hours to devote to sleep before becoming active. Until you know how you'll react to prescription Lunesta, you should not drive or operate machinery. Do not use alcohol while taking Lunesta. Most sleep medicines carry some risk of dependency. Side effects may include unpleasant taste, headache, drowsiness and dizziness. See important patient information on the next page.

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Lunesta™
(eszopiclone)
1, 2 AND 3 MG TABLETS

Please read this summary of information about LUNESTA before you talk to your doctor or start using LUNESTA. It is not meant to take the place of your doctor's instructions. If you have any questions about LUNESTA tablets, be sure to ask your doctor or pharmacist.

LUNESTA is used to treat different types of sleep problems, such as difficulty in falling asleep, difficulty in maintaining sleep during the night, and waking up too early in the morning. Most people with insomnia have more than one of these problems. You should take LUNESTA immediately before going to bed because of the risk of falling.

LUNESTA belongs to a group of medicines known as "hypnotics" or, simply, sleep medicines. There are many different sleep medicines available to help people sleep better. Insomnia is often transient and intermittent. It usually requires treatment for only a short time, usually 7 to 10 days up to 2 weeks. If your insomnia does not improve after 7 to 10 days of treatment, see your doctor, because it may be a sign of an underlying condition. Some people have chronic sleep problems that may require more prolonged use of sleep medicine. However, you should not use these medicines for long periods without talking with your doctor about the risks and benefits of prolonged use.

Side Effects

All medicines have side effects. The most common side effects of sleep medicines are:

- Drowsiness
- Dizziness
- Lightheadedness
- Difficulty with coordination

Sleep medicines can make you sleepy during the day. How drowsy you feel depends upon how your body reacts to the medicine, which sleep medicine you are taking, and how large a dose your doctor has prescribed. Daytime drowsiness is best avoided by taking the lowest dose possible that will still help you sleep at night. Your doctor will work with you to find the dose of LUNESTA that is best for you. Some people taking LUNESTA have reported next-day sleepiness.

To manage these side effects while you are taking this medicine:

- When you first start taking LUNESTA or any other sleep medicine, until you know whether the medicine will still have some effect on you the next day, use extreme care while doing anything that requires complete alertness, such as driving a car, operating machinery, or piloting an aircraft.
- Do not drink alcohol when you are taking LUNESTA or any sleep medicine. Alcohol can increase the side effects of LUNESTA or any other sleep medicine.
- Do not take any other medicines without asking your doctor first. This includes medicines you can buy without a prescription. Some medicines can cause drowsiness and are best avoided while taking LUNESTA.
- Always take the exact dose of LUNESTA prescribed by your doctor. Never change your dose without talking to your doctor first.

Special Concerns

There are some special problems that may occur while taking sleep medicines.

Memory Problems

Sleep medicines may cause a special type of memory loss or "amnesia." When this occurs, a person may not remember what has happened for several hours after taking the medicine. This is usually not a problem since most people fall asleep after taking the medicine. Memory loss can be a problem, however, when sleep medicines are taken while traveling, such as during an airplane flight and the person wakes up before the effect of the medicine is gone. This has been called "traveler's amnesia." Memory problems have been reported rarely by patients taking LUNESTA in clinical studies. In most cases, memory problems can be avoided if you take LUNESTA only when you are able to get a full night of sleep before you need to be active again. Be sure to talk to your doctor if you think you are having memory problems.

Tolerance

When sleep medicines are used every night for more than a few weeks, they may lose their effectiveness in helping you sleep. This is known as "tolerance." Development of tolerance to LUNESTA was not observed in a clinical study of 6 months' duration. Insomnia is often transient and intermittent, and prolonged use of sleep medicines is generally not necessary. Some people, though, have chronic sleep problems that may require more prolonged use of sleep medicine. If your sleep problems continue, consult your doctor, who will determine whether other measures are needed to overcome your sleep problems.

Dependence

Sleep medicines can cause dependence in some people, especially when these medicines are used regularly for longer than a few weeks or at high doses. Dependence is the need to continue taking a medicine because stopping it is unpleasant. When people develop dependence, stopping the medicine suddenly may cause unpleasant symptoms (see *Withdrawal* below). They may find they have to keep taking the medicine either at the prescribed dose or at increasing doses just to avoid withdrawal symptoms.

All people taking sleep medicines have some risk of becoming dependent on the medicine. However, people who have been dependent on alcohol or other drugs in the past may have a higher chance of becoming addicted to sleep medicines. This possibility must be considered before using these medicines for more than a few weeks. If you have been addicted to alcohol or drugs in the past, it is important to tell your doctor before starting LUNESTA or any sleep medicine.

Withdrawal

Withdrawal symptoms may occur when sleep medicines are stopped suddenly after being used daily for a long time. In some cases, these symptoms can occur even if the medicine has been used for only a week or two. In mild cases, withdrawal symptoms may include unpleasant feelings. In more severe cases, abdominal and muscle cramps, vomiting, sweating, shakiness, and, rarely, seizures may occur. These more severe withdrawal symptoms are very uncommon. Although withdrawal symptoms have not been observed in the relatively limited controlled trials experience with LUNESTA, there is, nevertheless, the risk of such events in association with the use of any sleep medicine.

Another problem that may occur when sleep medicines are stopped is known as "rebound insomnia." This means that a person may have more trouble sleeping the first few nights after the medicine is stopped than before starting the medicine. If you should experience rebound insomnia, do not get discouraged. This problem usually goes away on its own after 1 or 2 nights.

If you have been taking LUNESTA or any other sleep medicine for more than 1 or 2 weeks, do not stop taking it on your own. Always follow your doctor's directions.

Changes In Behavior And Thinking

Some people using sleep medicines have experienced unusual changes in their thinking and/or behavior. These effects are not common. However, they have included:

- More outgoing or aggressive behavior than normal
- Confusion
- Strange behavior
- Agitation
- Hallucinations
- Worsening of depression
- Suicidal thoughts

How often these effects occur depends on several factors, such as a person's general health, the use of other medicines, and which sleep medicine is being used. Clinical experience with LUNESTA suggests that it is rarely associated with these behavior changes.

It is also important to realize it is rarely clear whether these behavior changes are caused by the medicine, are caused by an illness, or have occurred on their own. In fact, sleep problems that do not

improve may be due to illnesses that were present before the medicine was used. If you or your family notice any changes in your behavior, or if you have any unusual or disturbing thoughts, call your doctor immediately.

Pregnancy And Breastfeeding

Sleep medicines may cause sedation or other potential effects in the unborn baby when used during the last weeks of pregnancy. Be sure to tell your doctor if you are pregnant, if you are planning to become pregnant, or if you become pregnant while taking LUNESTA.

In addition, a very small amount of LUNESTA may be present in breast milk after use of the medication. The effects of very small amounts of LUNESTA on an infant are not known; therefore, as with all other prescription sleep medicines, it is recommended that you not take LUNESTA if you are breastfeeding a baby.

Safe Use Of Sleep Medicines

To ensure the safe and effective use of LUNESTA or any other sleep medicine, you should observe the following cautions:

1. LUNESTA is a prescription medicine and should be used ONLY as directed by your doctor. Follow your doctor's instructions about how to take, when to take, and how long to take LUNESTA.
2. Never use LUNESTA or any other sleep medicine for longer than directed by your doctor.
3. If you notice any unusual and/or disturbing thoughts or behavior during treatment with LUNESTA or any other sleep medicine, contact your doctor.
4. Tell your doctor about any medicines you may be taking, including medicines you may buy without a prescription and herbal preparations. You should also tell your doctor if you drink alcohol. DO NOT use alcohol while taking LUNESTA or any other sleep medicine.
5. Do not take LUNESTA unless you are able to get 8 or more hours of sleep before you must be active again.
6. Do not increase the prescribed dose of LUNESTA or any other sleep medicine unless instructed by your doctor.
7. When you first start taking LUNESTA or any other sleep medicine, until you know whether the medicine will still have some effect on you the next day, use extreme care while doing anything that requires complete alertness, such as driving a car, operating machinery, or piloting an aircraft.
8. Be aware that you may have more sleeping problems the first night or two after stopping any sleep medicine.
9. Be sure to tell your doctor if you are pregnant, if you are planning to become pregnant, if you become pregnant, or if you are breastfeeding a baby while taking LUNESTA.
10. As with all prescription medicines, never share LUNESTA or any other sleep medicine with anyone else. Always store LUNESTA or any other sleep medicine in the original container and out of reach of children.
11. Be sure to tell your doctor if you suffer from depression.
12. LUNESTA works very quickly. You should only take LUNESTA immediately before going to bed.
13. For LUNESTA to work best, you should not take it with or immediately after a high-fat, heavy meal.
14. Some people, such as older adults (i.e., ages 65 and over) and people with liver disease, should start with the lower dose (1 mg) of LUNESTA. Your doctor may choose to start therapy at 2 mg. In general, adults under age 65 should be treated with 2 or 3 mg.
15. Each tablet is a single dose; do not crush or break the tablet.

Note: This summary provides important information about LUNESTA. If you would like more information, ask your doctor or pharmacist to let you read the Prescribing Information and then discuss it with him or her.

Rx only

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VISIONS OF EARTH

Guangxi Zhuangzu region, China Chandeliers and pillars of stone, their edges and shadows doubled in the glass-smooth surface of an underground pool, have awed visitors to the Reed Flute Cave for more than a thousand years.

PHOTO: JAMES P. NELSON, TCS



Monterey Bay Aquarium, California Sparkling like underwater fireworks, this six-inch-wide *Olindias* jellyfish displays an extravagantly curled and colored armament of tentacles loaded with stinging cells.



PHOTO: FRANS LANTING



Doha, Qatar As the 2006 Asian Games began, hundreds of men proudly held torches aloft, forming an image of the host nation's flag, then the burning message "Peace be upon you," in English and Arabic.



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PHOTO: PAUL GILHAM, GETTY IMAGES

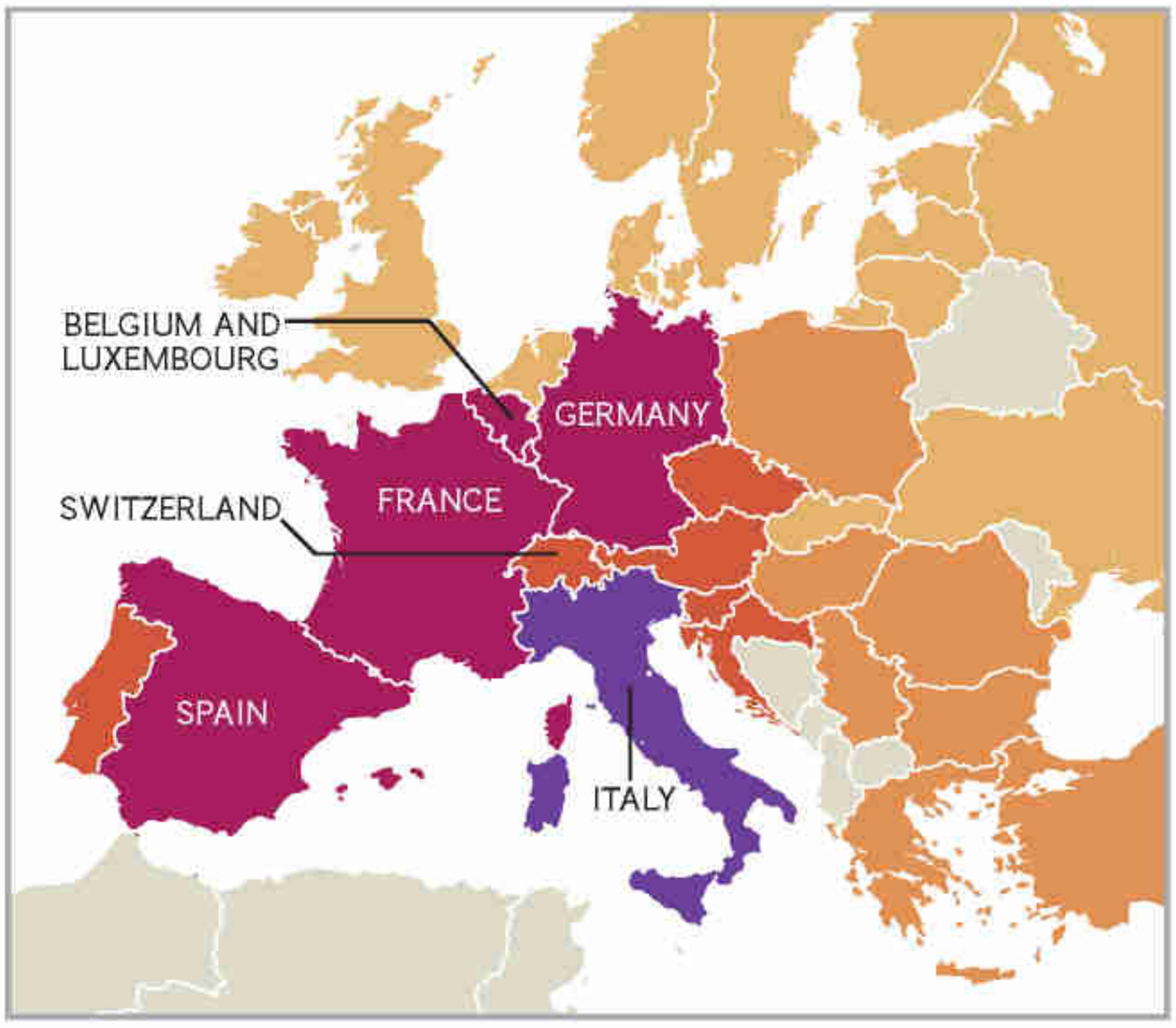


Bottles Up!

Europeans lead the world in drinking bottled water (right), but they've got plenty of company.



People are switching to water from other drinks, helping pump up global demand from 28 to 47 billion gallons between 2000 and 2006. But a lack of public recycling bins means that many single-serve empties get trashed. By one estimate, U.S. drinkers toss 60 million plastic water bottles a day. If the environmental costs—such as the greenhouse gases released to make and ship so many bottles—don't change habits, think of the bottom line. Sixteen ounces of bottled water can cost more than a dollar; from the tap it's less than a penny. —*Alan Mairson*



WHO DRINKS THE MOST BOTTLED WATER

Top ten markets, by liters per person in 2006

203	Italy	129	Germany
197	United Arab Emirates	126	Spain
191	Mexico	117	Lebanon
149	France	110	Switzerland
145	Belgium/Luxembourg	104	United States

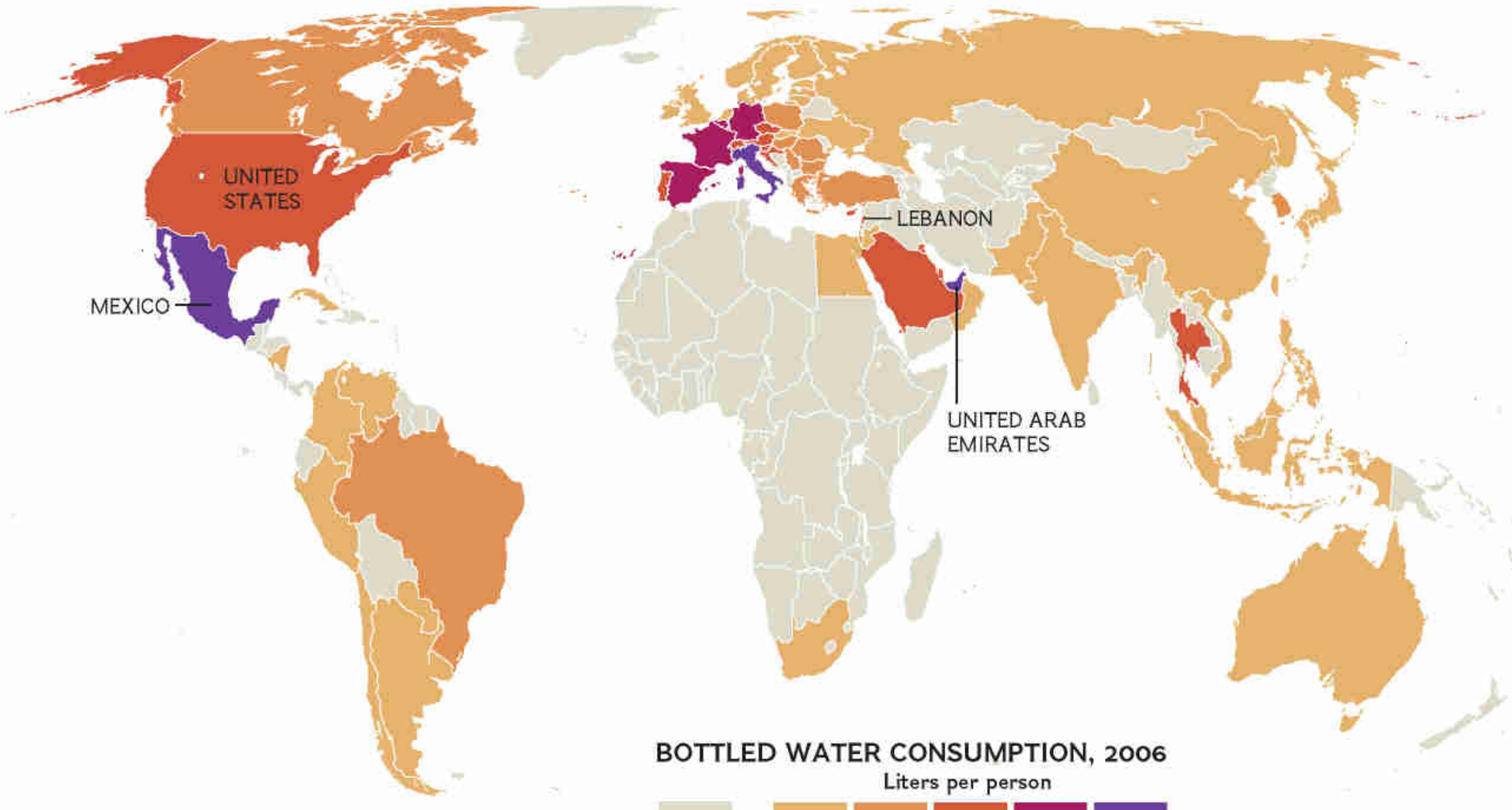
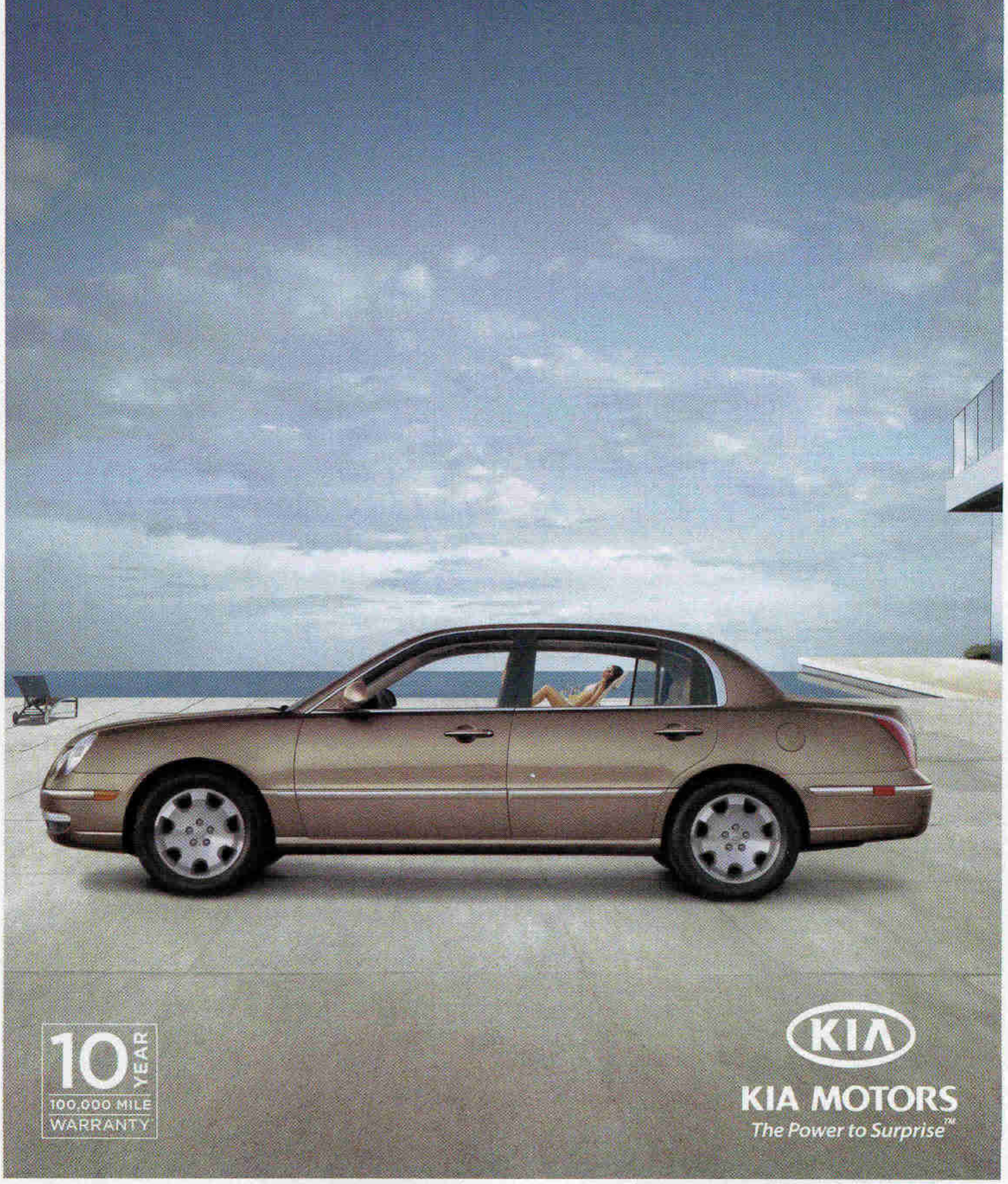


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Trapped, crammed into a container, and shipped off to life in a cage. That's the fate of many wild birds, like this blue-fronted Amazon parrot. A ban will now keep them out of Europe.

Bird Reins Mainly because of the threat of avian flu, wild birds are no longer welcome on the continent that adores them most. In 2005, before a temporary ban, Europe imported an estimated 1.5 million exotic birds as pets, 90 percent of the world total. This month, the European Union has permanently closed its borders to wild-caught birds. Dissenters say the ban will boost the black market, where disease is harder to monitor. "Legal trade provides cover for illegal trade," counters Ann Michels of the Species Survival Network. Threatened and endangered birds had previously been regulated. Stemming all imports, she says, will "actually reduce the opportunity for laundering and smuggling." But legitimate trappers will lose part of their livelihood. The Convention on International Trade in Endangered Species commiserates: It endorses sustainable use of local birds for income. *—Jennifer S. Holland*

PHOTO: WORLD PARROT TRUST

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Super Steady Shot Inside



A Spaniard's iron musket ball blasted a piece (below left) out of the skull of the New World's first known shooting victim (above).



NG GRANTEE **Shot by a Conquistador** The bodies found in the path of a planned expressway near Lima showed signs of terrible violence. Nearly 500 years ago, about 70 men, women, and adolescents were hacked, torn, and impaled—and some looked as if they were shot. The sandy soil of the burial ground preserved the bones, saving valuable forensic evidence from the era when Europeans subjugated the Americas, says Guillermo Cock, a Peruvian archaeologist excavating Inca cemeteries. And the musket wounds offered a clue to the identity of the killers. "We know many natives were killed by European weapons during colonial conquest," he says. "This may be the first time the evidence has been found." Based on precolonial burials in the same cemetery, Cock believes the killings took place in the summer of 1536 during an Inca uprising against the Spanish occupiers. In that confrontation, the superior weaponry of Francisco Pizarro and his fellow conquistadores helped carry the day. *—Chris Carroll*

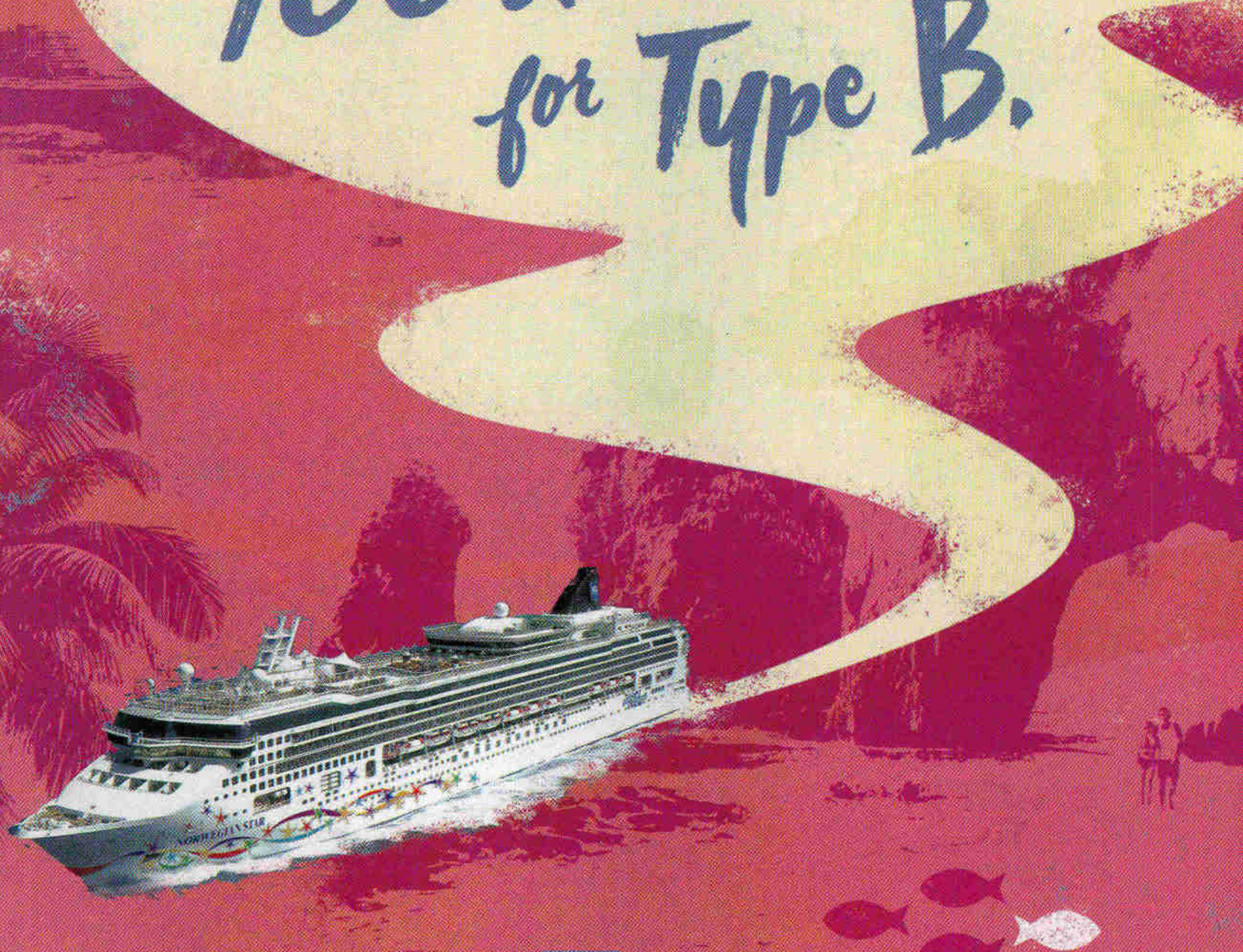


NOVA–National Geographic Special

The Great Inca Rebellion, airing June 26 on PBS, traces the 1536 uprising.

PHOTOS: ELENA GOYCOCHEA, PURUCHUCO-HUAQUERONES ARCHAEOLOGICAL PROJECT (TOP); REBECCA HALE, NGS STAFF (LEFT)

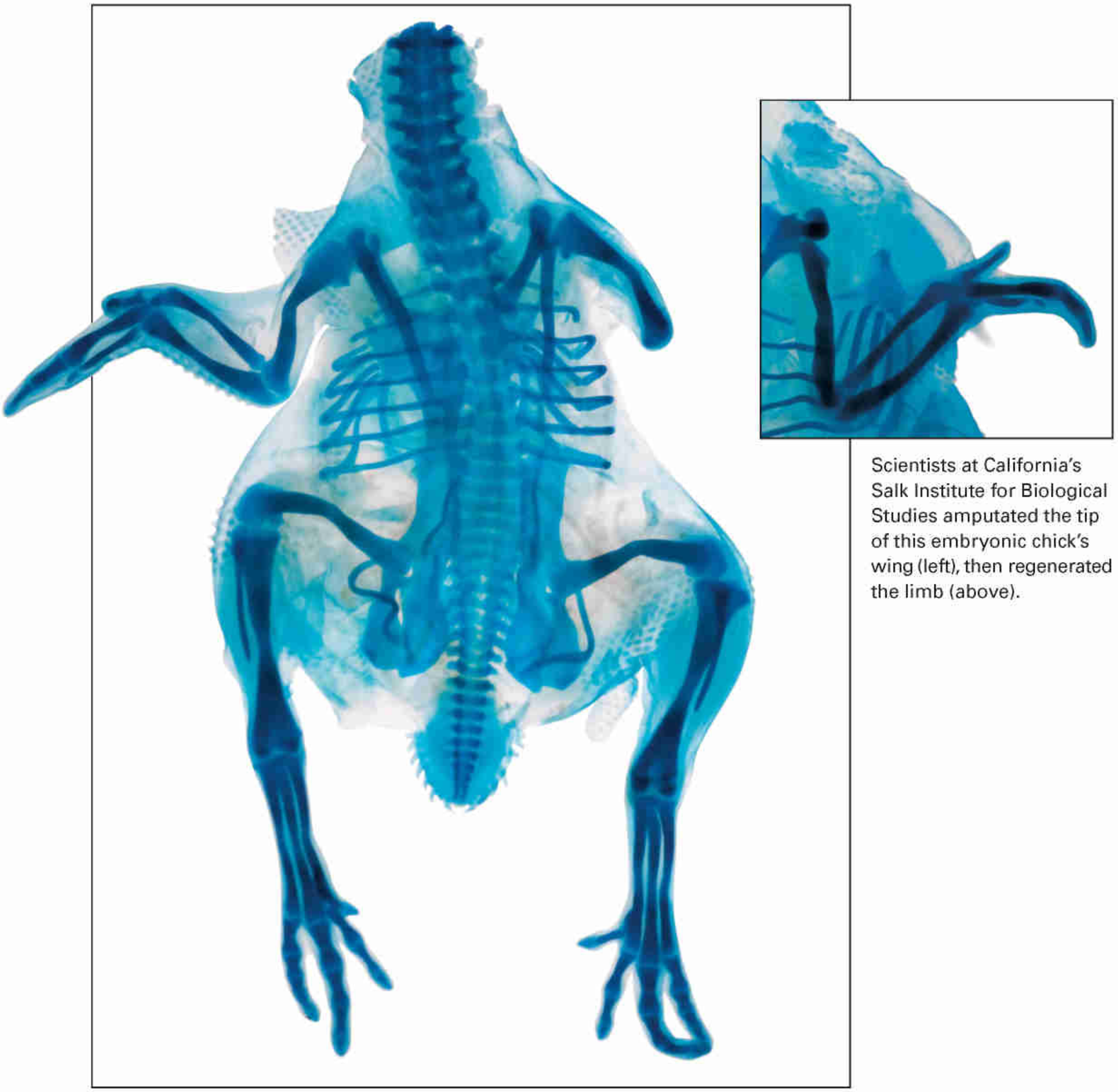
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Scientists at California's Salk Institute for Biological Studies amputated the tip of this embryonic chick's wing (left), then regenerated the limb (above).

Winging It They snipped off a wing of an embryonic chicken at the Salk Institute for Biological Studies, and grew a new wing in its place. That's no feat for stone crabs (take but one claw at a time and another sweet pincer will take its place down the line), but for chickens, it's a first. By changing expression of a few genes, says Salk's Juan Carlos Izpisúa Belmonte, scientists "got the whole limb back—a beautiful and perfect wing." It will be a long time before this knowledge might be put to use in humans. But it's encouraging to learn that scientists can, in Belmonte's words, "change the ability of a vertebrate to regenerate limbs, rebuilding blood vessels, bone, muscles, and skin—everything that is needed." Except lips. *—Gregory Jaynes*

PHOTOS: DON BARTLETTI

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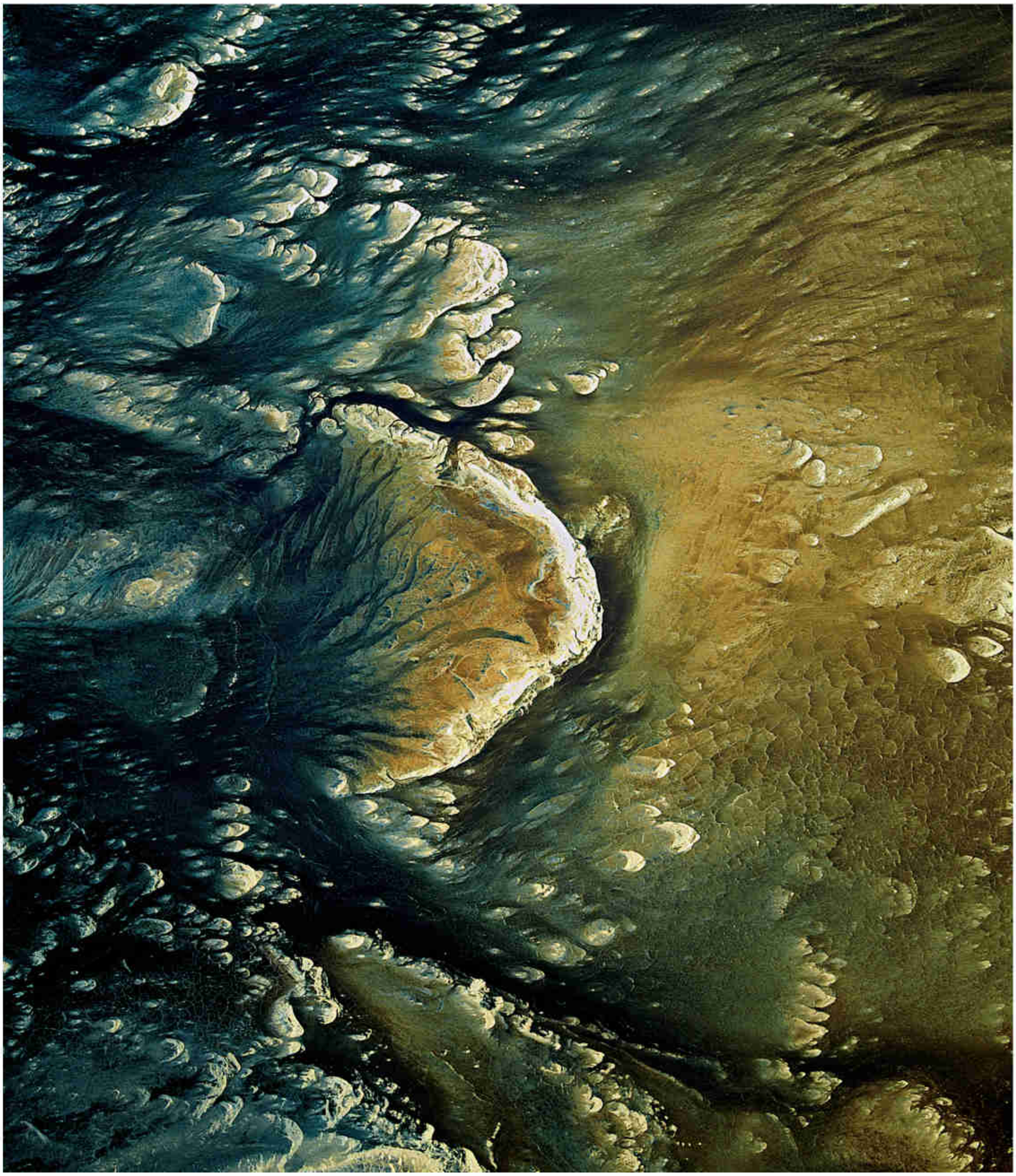
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WHERE IN THE WORLD?



Lake Natron's southern tip is stippled with white soda deposits from the Ol Doinyo Lengai volcano.

Woebegone Lake Not far from the cradle of humanity lies a body of water in which humans wouldn't care to dip a toe. At the semiarid bottom of the Rift Valley Basin, Tanzania's Lake Natron holds some of Earth's saltiest and hottest waters—in places 122°F. Once a fulsome freshwater body, the lake has gradually evaporated over millennia; it's now less than ten feet deep. Yet life yawps in this alkaline serum. On wrinkled mudflats, flocks of lesser flamingos feed on blue-green algae, while greater flamingos feast on copepod larvae that thrive in the shallows. *—Peter Gwin*

PHOTO: BERNHARD EDMAIER

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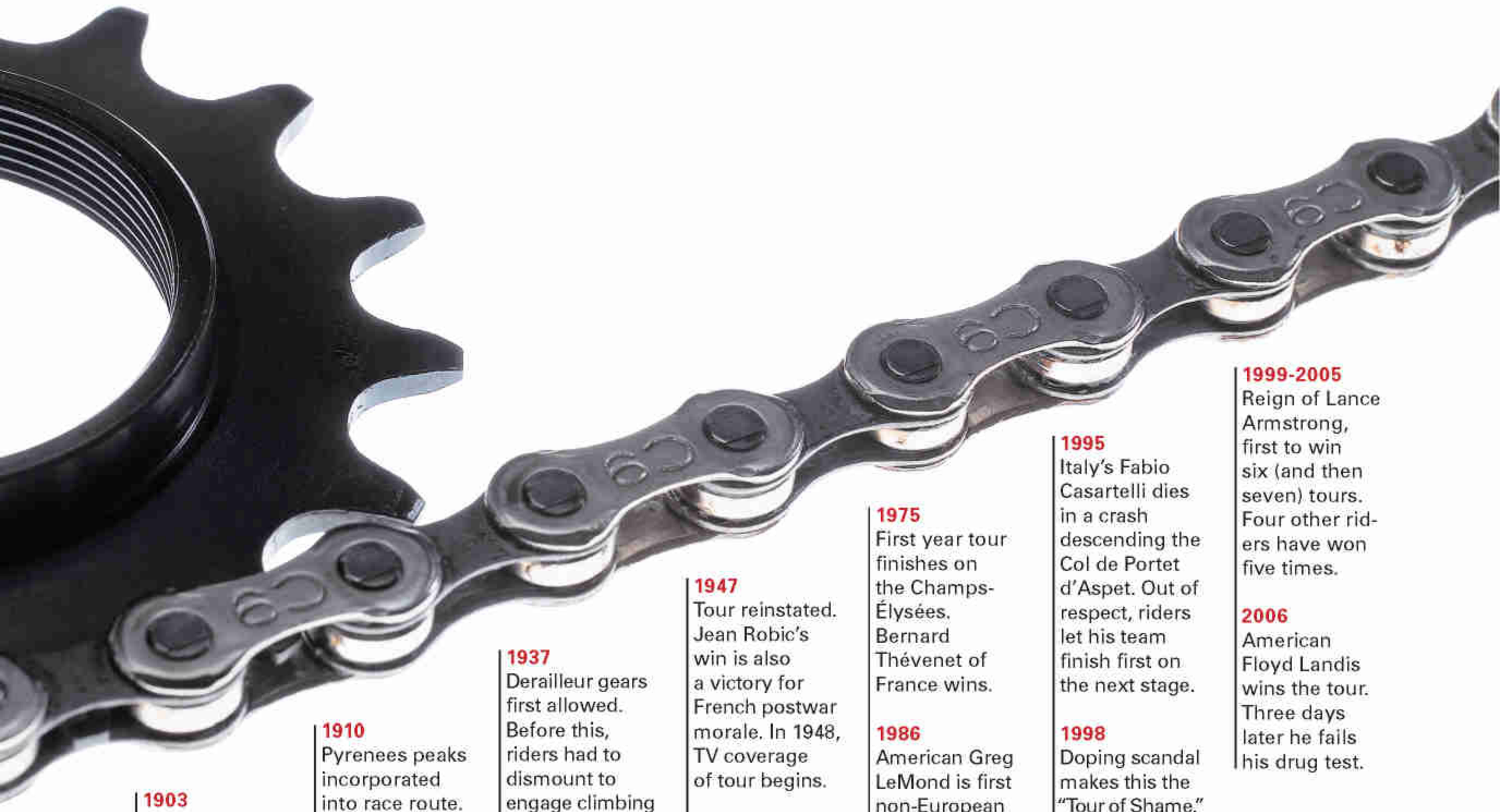
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Chain Gang

This month the 94th Tour de France begins—in England. The three-week race has always celebrated Gallic geography. Its forays into other nations increased after World War II as an early nod to European unity, says historian Christopher S. Thompson. Cities as distant as Quebec now join French towns to bid for profitable spots on the race's route, which typically covers about 2,300 miles. They may all get a chance yet. "From one year to the next," says Thompson, "the itinerary has never been exactly the same." *—Margaret G. Zackowitz*



Tour de France riders smoke the competition—and cigarettes—in the 1920s.



1903
A French newspaper, *L'Auto,* founds the Tour de France as a promotional event.

1910
Pyrenees peaks incorporated into race route. The next year, the Alps are added.

1915-1918
Tour halted during World War I. In 1919, the lead rider's yellow jersey is introduced—the color of *L'Auto*'s pages.

1937
Derailleur gears first allowed. Before this, riders had to dismount to engage climbing gears by hand.

1940-1946
Tour stopped again during World War II. German occupying forces push organizers to hold tours but are denied.

1947
Tour reinstated. Jean Robic's win is also a victory for French postwar morale. In 1948, TV coverage of tour begins.

1965
French law bans stimulant drug use in athletic competitions. In 1966, tour racers are first tested for drugs.

1975
First year tour finishes on the Champs-Élysées. Bernard Thévenet of France wins.

1986
American Greg LeMond is first non-European winner. In 1989, he wins by eight seconds, tightest margin ever. He claims a third win in 1990.

1995
Italy's Fabio Casartelli dies in a crash descending the Col de Portet d'Aspet. Out of respect, riders let his team finish first on the next stage.

1998
Doping scandal makes this the "Tour of Shame." Riders stage a sit-down strike after police search their hotels for drugs.

1999-2005
Reign of Lance Armstrong, first to win six (and then seven) tours. Four other riders have won five times.

2006
American Floyd Landis wins the tour. Three days later he fails his drug test.

PHOTOS: PRESS 'E SPORTS (TOP); REBECCA HALE, NGS STAFF

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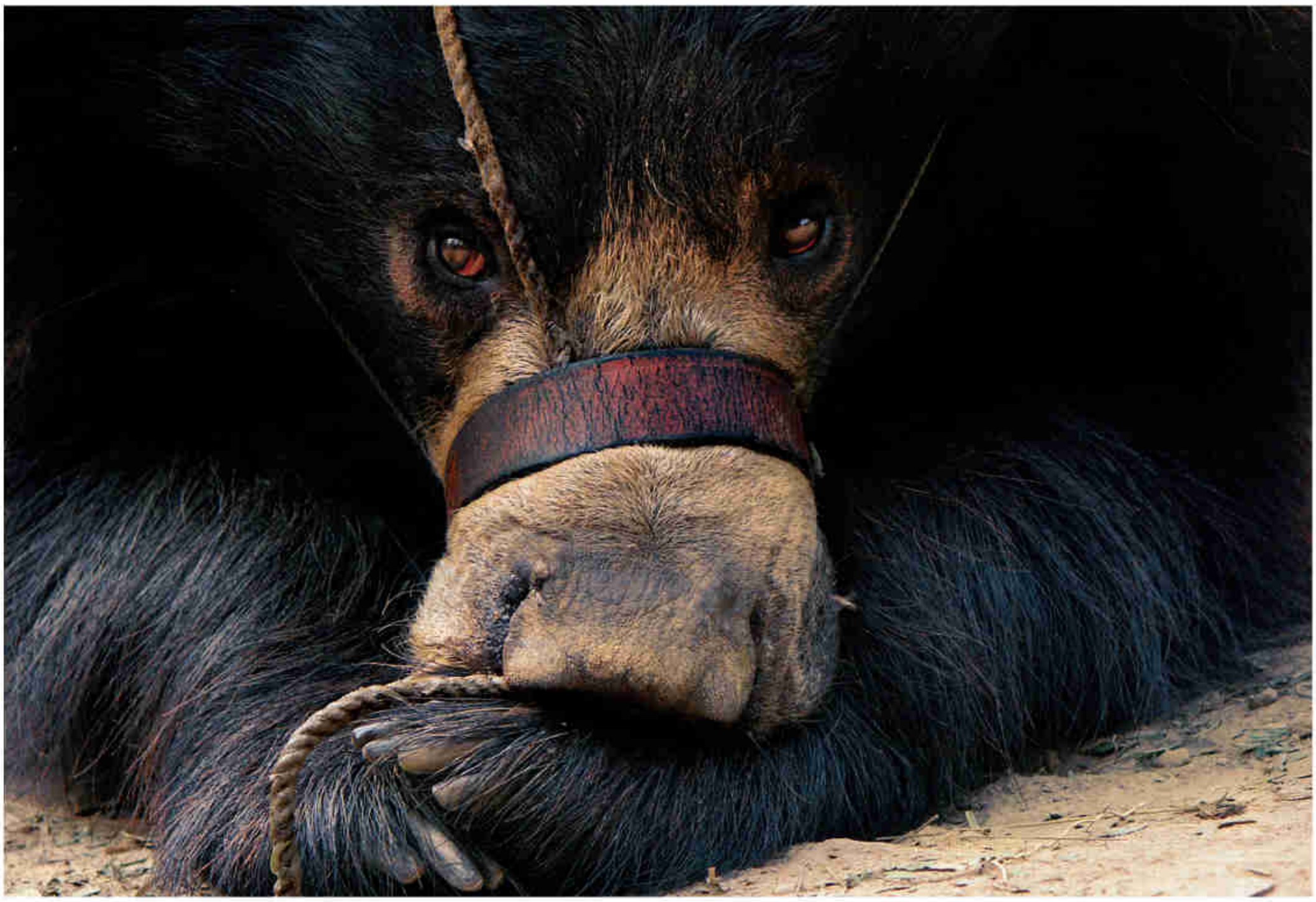




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Bears' Last Dance The life of India's so-called dancing bears looks like torture: Captured as cubs, the shaggy, insect-eating sloth bears are trained to "dance" for coin-tossing tourists as a handler tugs on a rope punched through a hole in the snout. Their handlers often knock out some teeth to render the animals less dangerous. Others suffer infections or go blind from malnutrition or disease. While illegal, the ancient practice persists in many areas.

Now the captive bruins are getting a second chance. Since 1999, Wildlife SOS, working with the Indian government, has created three rehabilitation centers for sloth bears. The group convinces handlers to surrender their animals; in exchange, it provides job training and education for those who depend on the bears for a livelihood. So far, more than 380 bears have been rescued, but more work lies ahead: Even now, some 600 stagger and sway on the streets, and cubs are still ripped from the wild to become new dancers. *—Neil Shea*





A captive sloth bear (top) has a leash threaded through its snout. At a bear rehabilitation center, a rescued bear (left) plays with a keeper.

PHOTOS: JONATHAN PEARCE, ONE VOICE ASSOCIATION/WILDLIFE SOS (TOP); NEHA VASANT-DIDDEE

BATHROOM CONFIDENTIAL FROM AVODART

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"Arnold, so when do we add the revolving door to the bathroom?"

You probably think you have a going problem. Instead, it might be a growing problem.

If you not only have to go to the bathroom often, but find it's hard to start once you get there. Or see that you're starting and stopping, you may have an enlarging prostate. And you don't have to put up with it. Ask your doctor if *Avodart* is right for you. Most medicines only treat urinary symptoms. *Avodart,* with time, actually shrinks the prostate and reduces symptoms. So you can spend less time in the bathroom and more time in bed.

Important Safety Information About Prescription AVODART® (dutasteride): *Avodart* is used to treat urinary symptoms of Enlarging Prostate. Only your doctor can tell if your symptoms are from an enlarged prostate and not a more serious condition, such as prostate cancer. See your doctor for regular exams. Women and children should not take *Avodart.* Women who are or could become pregnant should not handle *Avodart* due to the potential risk of a specific birth defect. Do not donate blood until at least six months after stopping *Avodart.* Tell your doctor if you have liver disease. *Avodart* may not be right for you. Possible side effects, including sexual side effects and swelling or tenderness of the breast, occur infrequently. ***See important information on next page.***

Do you have an enlarging prostate?

If you have any of these urinary symptoms, talk to your doctor.

- Urination starts and stops.
- Frequent urge to urinate.
- Difficulty emptying your bladder.
- Symptoms get in the way of your life.
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Soft Gelatin Capsules 0.5 mg

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AVODART® (dutasteride)

Read the information you get with AVODART before you start taking it and each time you refill your prescription. There may be new information. This information does not take the place of talking with your doctor.

What is AVODART?

AVODART is a medication for the treatment of symptoms of benign prostatic hyperplasia (BPH) in men with an enlarged prostate to:

- Improve symptoms
- Reduce the risk of acute urinary retention (a complete blockage of urine flow)
- Reduce the risk of the need for BPH-related surgery

AVODART is not a treatment for prostate cancer.

Who should NOT take AVODART?

- Women and children should not take AVODART. A woman who is pregnant or capable of becoming pregnant should not handle AVODART capsules.
- If a woman who is pregnant with a male baby gets enough AVODART into her body after swallowing it or through her skin after handling it, the male baby may be born with abnormal sex organs.
- Do not take AVODART if you have had an allergic reaction to AVODART or any of its ingredients.

What are the special precautions about AVODART?

- Men treated with AVODART should not donate blood until at least 6 months after their final dose to prevent giving AVODART to a pregnant female through a blood transfusion.
- Tell your doctor if you have liver problems. AVODART may not be right for you.
- A blood test called PSA (prostate-specific antigen) is sometimes used to detect prostate cancer. AVODART will reduce the amount of PSA measured in your blood. Your doctor is aware of this effect and can still use PSA to detect prostate cancer in you.

What are the possible side effects of AVODART?

Possible side effects are impotence (trouble getting or keeping an erection), a decrease in libido (sex drive), enlarged breasts, a decrease in the amount of semen released during sex, and allergic reactions such as rash, itching, hives, and swelling of the lips or face. These events occurred infrequently.

Talk with your doctor if you have questions about these and other side effects that you think may be related to taking AVODART.

If you don't have prescription coverage, visit pparx.org, or call 1-888-4PPA-NOW (1-888-477-2669)

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Actual size is 30.6 mm

"O" Mark of the New Orleans Mint

Secret Confederate Treasure Discovered in Lost Civil War Shipwreck!

For 150 years experts have known that the Confederacy produced silver half dollars dated 1861 and bearing the "O" of the New Orleans Mint. But no one knew what became of them. Only 4 were known to have been struck with the seal of the Confederacy, one of which sold at auction for $632,500.

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The team of Odyssey Marine Exploration made headlines worldwide when, after years of searching, they found the shipwreck of the SS *Republic*®. In 1865 the steamship went down in a hurricane, settling 1,700 feet beneath the Atlantic. Odyssey knew the SS *Republic* carried a king's ransom in U.S. gold coins from the Civil War era. But a secret awaited their discovery.

There among the glittering gold coins Odyssey brought up from the SS *Republic*: Silver half dollars bearing the date "1861" and the "O" mint mark of the old New Orleans Mint. "I could hardly believe my eyes," recalls Odyssey co-founder Greg Stemm. "We'd pored over the historical records. There was no reference to these coins in our research. We were surprised…and mystified".

The 1861-O half dollars were entrusted to the world's foremost experts. After months of painstaking study and research with government records, the weight of evidence was overwhelming. Numismatic Guaranty Corp (NGC), the nation's foremost independent rare coin conservation and grading service, was able to attribute and certify individual 1861-O silver half dollars found on the SS *Republic* to the Confederate States of America.

An Extraordinary Opportunity — If You Act Now. Authentic artifacts of the Civil War are highly coveted today. Many are locked away in museums such as the Smithsonian or are beyond the reach of all but the wealthiest. An original Confederate Army coat has sold for $70,000. A CSA flag brought a record $956,000. A Civil War canteen brings $5,500. Today, due to this history-making discovery, you can be one of the first to own an 1861-O silver half dollar, officially attributed to the Confederate States of America, from the fabulous treasure of the SS *Republic*. A limited number are being released to the public for just $1,497 (plus shipping and insurance).



Your Civil War treasure coin is certified and encapsulated by NGC and housed in a deluxe hardwood presentation case. The SS *Republic* DVD and a booklet detailing the amazing story of the New Orleans Mint at the beginning of the Civil War are also included.

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It will be housed in a magnificent hardwood presentation case and accompanied by a DVD about the amazing discovery of the SS *Republic*.

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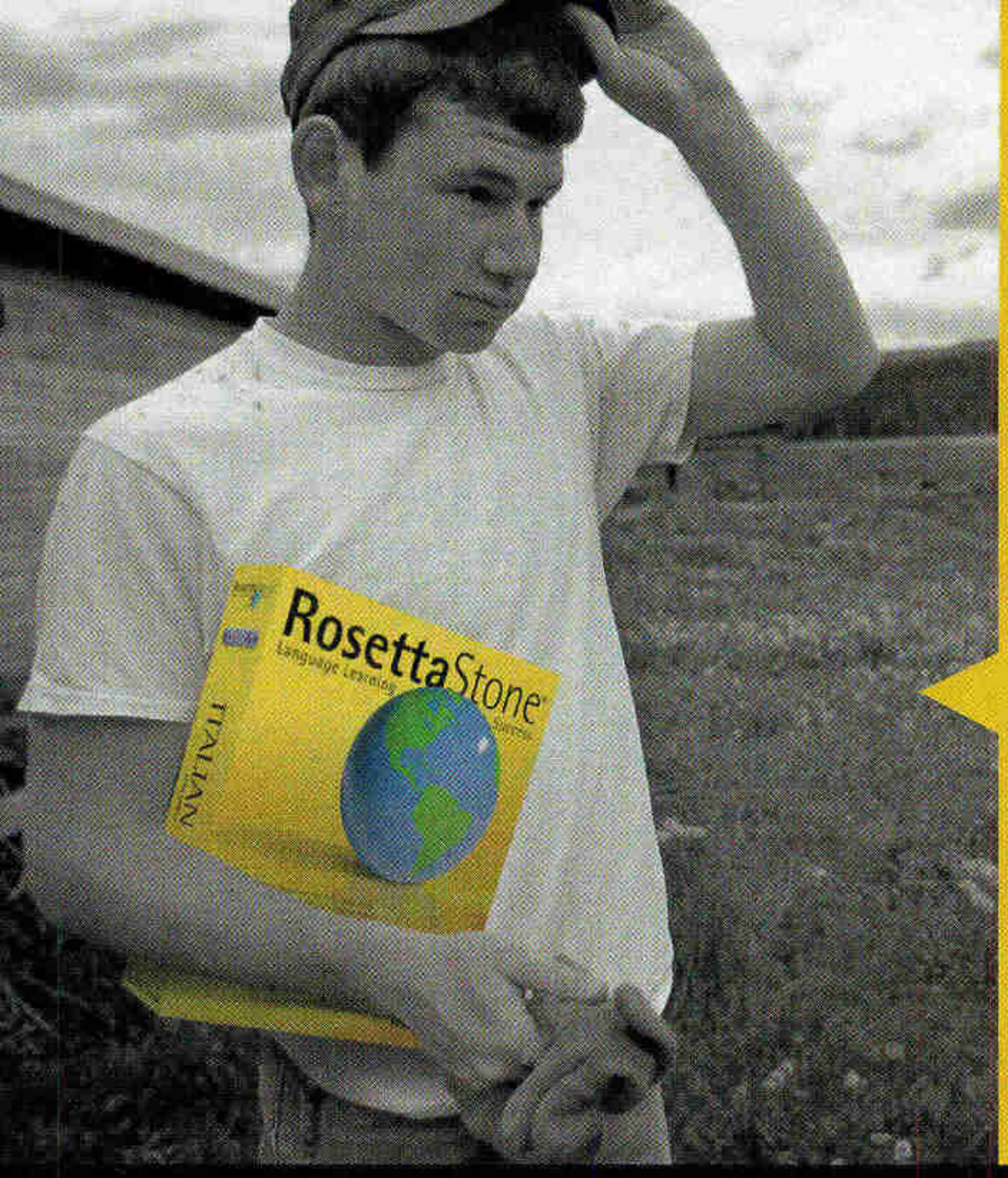
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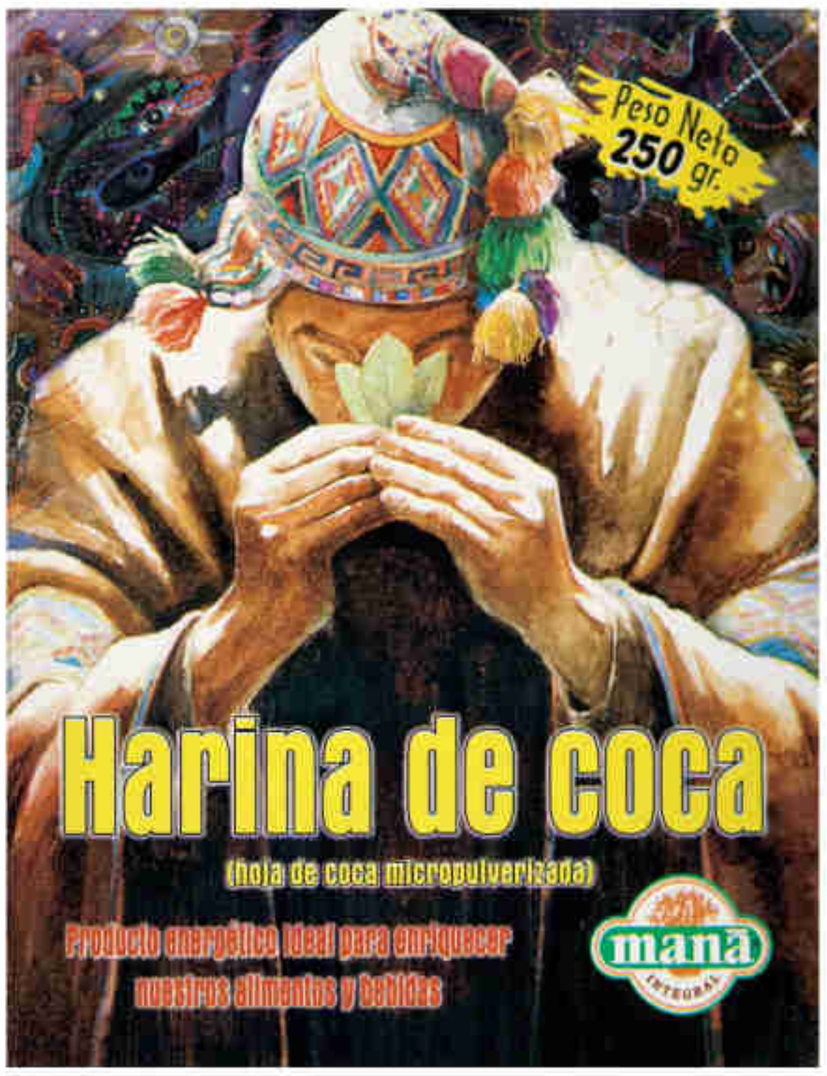
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Hot Coca "Yes to coca, no to cocaine." That's the slogan of Evo Morales, Bolivia's first indigenous president, as he battles the 46-year-old United Nations ban on the international trade of coca. Mainly targeting cocaine, the coca plant's infamous derivative, the ban blocks exports from Bolivia, Colombia, and Peru that use the leaf in legal coca-based items—even a soda called Evo Cola.

Morales has politicized the plant's cultural roots, as have manufacturers. "To defend coca is to defend our sovereignty" is printed on bags of coca flour from Peru (right). Long before Europeans arrived, the people of the Andes made ritual offerings of the *hoja sagrada,* or sacred leaf, and chewed it as a mild stimulant—traditions that continue today. Modern coca goods give the same lift, much like coffee, along with vitamins and minerals. The leaf's buzz-producing alkaloids are absorbed only in minute amounts during digestion. Snorting cocaine, however, blasts super-concentrated alkaloids into the bloodstream for what can be a dangerous high. *—A. R. Williams*



FROM COCA LEAF TO GROCERY SHELF

Products made with powdered coca leaf cater to many tastes and provide many benefits. A 1975 Harvard study cited the leaf's protein, fiber, and calcium content. Coca leaf is also used in toothpastes, soaps, and skin creams.



PHOTOS: PABLO CORRAL VEGA

BEDLAM IN THE BLOOD

MALARIA

A female *Anopheles* mosquito acts as a deadly hypodermic, injecting the malaria parasite when she feeds on human blood. Nearly half a billion people get malaria each year. More than a million die. After decades of neglect, the world is renewing its fight against the disease.

COLOR-SYNTHESIZING SCANNING ELECTRON MICROSCOPE IMAGE BY DAVID SCHARF

BY MICHAEL FINKEL
PHOTOGRAPHS BY JOHN STANMEYER





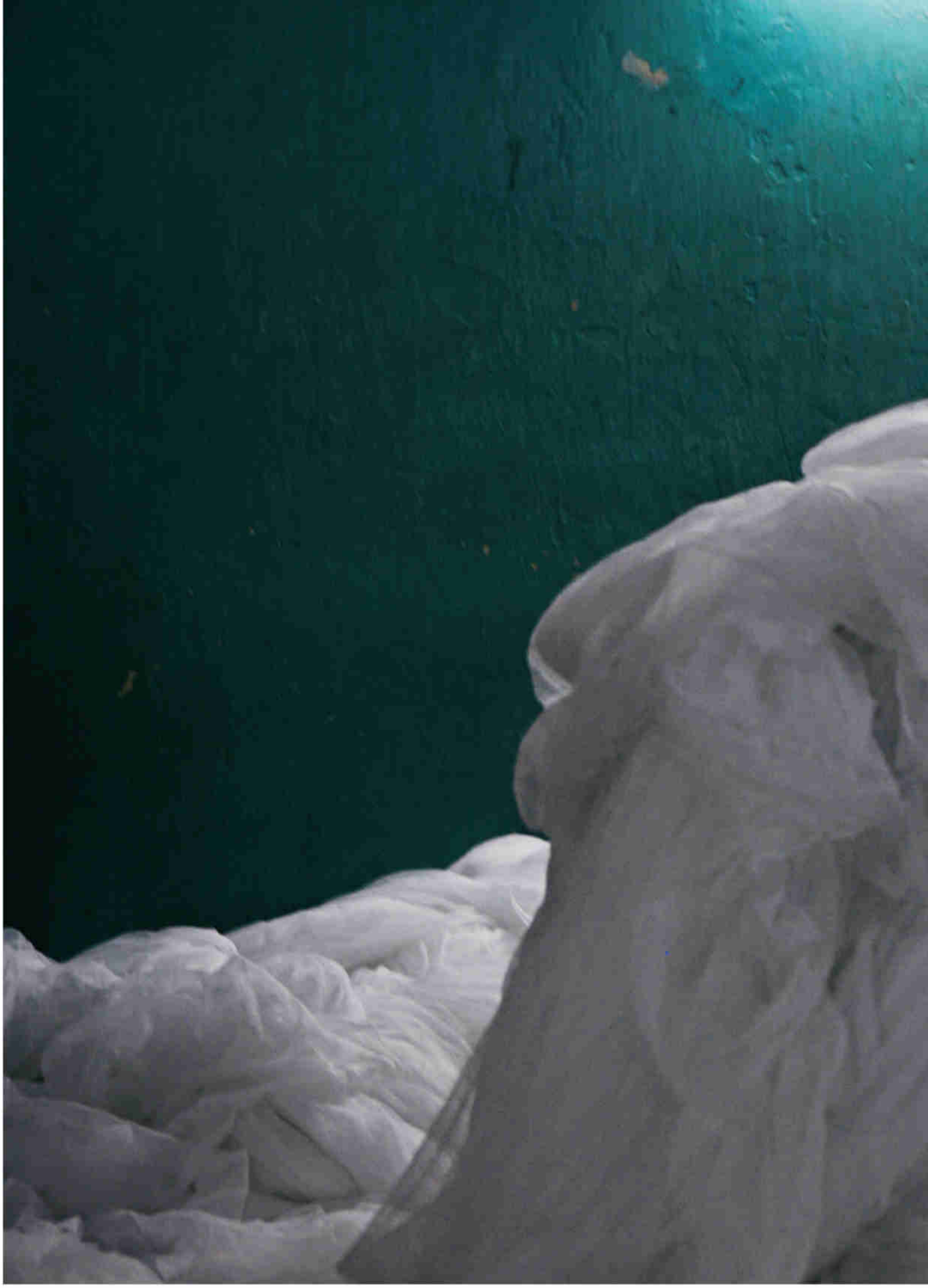


Those who love him can only watch and hope as four-year-old Edwin Malesu lies in a stupor, battling cerebral malaria in the Kalene hospital in Zambia. Some 3,000 children die of malaria each day in Africa, one every 30 seconds. Edwin was treated early and survived.





Rain that flooded a street in Kolkata (Calcutta), India, and stranded a taxi will provide places for malarial mosquitoes to lay their eggs as the waters recede into pools. Monsoon rains and poor drainage enable malaria to thrive in sections of Indian cities.





One of the best defenses against malaria is a gauzy piece of fabric—a mosquito net like these heaped in a factory in Tanzania, Africa's largest bed-net producer. Treated with insecticide and draped over beds, nets can cut infections by half and child deaths by a third.



It begins with a bite, a painless bite. The mosquito comes in the night, alights on an exposed patch of flesh, and assumes the hunched, head-lowered posture of a sprinter in the starting blocks. Then she plunges her stiletto mouthparts into the skin.

The mosquito has long, filament-thin legs and dappled wings; she's of the genus *Anopheles*, the only insect capable of harboring the human malaria parasite. And she's definitely a she: Male mosquitoes have no interest in blood, while females depend on protein-rich hemoglobin to nourish their eggs. A mosquito's proboscis appears spike-solid, but it's actually a sheath of separate tools—cutting blades and a feeding tube powered by two tiny pumps. She drills through the epidermis, then through a thin layer of fat, then into the network of blood-filled microcapillaries. She starts to drink.

FEMALE MOSQUITOES FEED ON WARM COW'S BLOOD AS PART OF A SCIENTIFIC EXPERIMENT. PHOTO: IRA BLOCK

To inhibit the blood from coagulating, the mosquito oils the bite area with a spray of saliva. This is when it happens. Carried in the mosquito's salivary glands—and entering the body with the lubricating squirt—are minute, worm-like creatures. These are the one-celled malaria parasites, known as plasmodia. Fifty thousand of them could swim in a pool the size of the period at the end of this sentence. Typically, a couple of dozen slip into the bloodstream. But it takes just one. A single plasmodium is enough to kill a person.

The parasites remain in the bloodstream for only a few minutes. They ride the flume of the circulatory system to the liver. There they stop. Each plasmodium burrows into a different liver cell. Almost certainly, the person who has been bitten hardly stirs from sleep. And for the next week or two, there's no overt sign that something in the body has just gone horribly wrong.

We live on a malarious planet. It may not seem that way from the vantage point of a wealthy country, where malaria is sometimes thought of, if it is thought of at all, as a problem that has mostly been solved, like smallpox or polio. In truth, malaria now affects more people than ever before. It's endemic to 106 nations, threatening half the world's population. In recent years, the parasite has grown so entrenched and has developed resistance to so many drugs that the most potent strains can scarcely be controlled. This year malaria will strike up to a half billion people. At least a million will die, most of them under age five, the vast majority living in Africa. That's more than twice the annual toll a generation ago.

The outcry over this epidemic, until recently, has been muted. Malaria is a plague of the poor, easy to overlook. The most unfortunate fact about malaria, some researchers believe, is that prosperous nations got rid of it. In the meantime, several distinctly unprosperous regions have reached the brink of total malarial collapse, virtually ruled by swarms of buzzing, flying syringes.

Only in the past few years has malaria captured the full attention of aid agencies and donors. The World Health Organization has made malaria reduction a chief priority. Bill Gates, who has called malaria "the worst thing on the planet," has donated hundreds of millions of dollars to the effort through the Bill and Melinda Gates Foundation. The Bush Administration has pledged 1.2 billion dollars. Funds devoted to malaria have doubled since 2003. The idea is to disable the disease by combining virtually every known malaria-fighting technique, from the ancient (Chinese herbal medicines) to the old (bed nets) to the ultramodern (multidrug cocktails). At the same time, malaria researchers are pursuing a long-sought, elusive goal: a vaccine that would curb the disease for good.

Much of the aid is going to a few hard-hit countries scattered across sub-Saharan Africa. If these nations can beat back the disease, they'll serve as templates for the global antimalaria effort. And if they can't? Well, nobody in the malaria world likes to answer that question.

One of these spotlighted countries—perhaps the place most closely watched by malaria experts—is Zambia, a sprawling, landlocked nation carved out of the fertile bushland of southern Africa. It's difficult to comprehend how thoroughly Zambia has been devastated by malaria. In some provinces, at any given moment, more than a third of all children under age five are sick with the disease.

Worse than the sheer numbers is the type of malaria found in Zambia. Four species of malaria parasites routinely infect humans; the most virulent, by far, is *Plasmodium falciparum.* About half of all malaria cases worldwide are caused by *falciparum,* and 95 percent of the deaths. It's the only form of malaria that can attack the brain. And it can do so with extreme speed—few infectious agents can overwhelm the body as swiftly as *falciparum.* An African youth can be happily playing soccer in the morning and dead of *falciparum* malaria that night.

Falciparum is a major reason nearly 20 percent of all Zambian babies do not live to see their fifth birthday. Older children and adults, too, catch the disease—pregnant women are especially prone—but most have developed just enough immunity to fight the parasites

to a stalemate, though untreated malaria can persist for years, the fevers fading in and out. There are times when it seems that everyone in Zambia is debilitated to some degree by malaria; many have had it a dozen or more times. No surprise that the nation remains one of the poorest in the world: A country's economic health has little chance of improving until its physical health is revitalized. Zambia's goal is to reduce malaria deaths by 75 percent over the next four years.

To witness the full force of malaria's stranglehold on Zambia, it's essential to leave the capital city, Lusaka. Drive north, across the verdant plains, past the banana plantations and the copper mines—copper is Zambia's primary export—and into the forested region tucked between the borders of Angola and the Democratic Republic of the Congo. This is the North-Western Province. It is almost entirely rural; many villages can be reached only by thin footpaths worn into the beet-red soil. A nationwide health survey in 2005 concluded that for every thousand children under age five living in the North-Western Province, there were 1,353 cases of malaria. An annual rate of more than 100 percent seems impossible, a typo. It is not. What it means is that many children are infected with malaria more than once a year.

In the North-Western Province, competent medical help can be difficult to find. For families living in the remote northern part of the province, across more than a thousand square miles of wild terrain, there is only one place that can ensure a reasonable chance of survival when severe malaria strikes a child: Kalene Mission Hospital. This modest health center, in a decaying brick building capped with a rusty tin roof, represents the front line in the conflict between malaria and man. Scientists at the world's high-tech labs ponder the secrets of the parasite; aid agencies solicit donations; pharmaceutical companies organize drug trials. But it is Kalene hospital—which functions with precisely one microscope, two registered nurses, occasional electricity from a diesel generator, and sometimes a doctor, sometimes not (though always with a good stock of antimalarial medicines)—that copes with malaria's victims.

Every year for a century, since Christian missionaries founded the hospital in 1906, the coming of the rainy season has marked the start of a desperate pilgrimage. Clouds gather; downpours erupt; mosquitoes hatch; malaria surges. There's no time to lose. Parents bundle up their sick children and make their way to Kalene hospital.

They come mostly on foot. Some walk for days. They follow trails across borders, into rivers, through brushwood. When they reach the hospital, each child's name is printed on a card and filed in a worn wooden box at the nurses' station. Florence, Elijah, Ashili. They come through the heat and the rain and the dead dark of the cloudy night. Purity, Watson, Miniva. Some unconscious, some screaming, some locked in seizure. Nelson, Japhious, Kukena.

Malaria now affects more people than ever before. It's endemic to 106 nations, threatening half the world's population.

A few families with bicycles, Chinese-made one-speeds, the father at the pedals, the mother on the seat, the child propped between. Delifia, Fideli, Sylvester. They fill up every bed in the children's ward, and they fill up the floor, and they fill up the courtyard. Methyline, Milton, Christine. They pour out of the bush, exhausted and dirty and panicked. They come to the hospital. And the battle for survival begins.

From the mosquito's salivary glands to the host's liver cell: a quiet trip. Everything seems fine. Even the liver itself, that reddish sack of blood-filtering cells, shows no sign of trouble. It's only in those few rooms whose locks have been picked by *falciparum* where all is pandemonium. Inside these cells, the malaria parasites eat and multiply. They do this nonstop for about a week, until the cell's original contents

have been entirely digested and it is bulging with parasites like a soup can gone bad. Each *falciparum* that entered the body has now replicated itself 40,000 times.

The cells explode. A riot of parasites is set loose in the bloodstream. Within 30 seconds, though, the parasites have again entered the safe houses of cells—this time, each has drilled into a red blood cell, flowing through the circulatory system. Over the next two days, the parasites continue to devour and proliferate stealthily. After they have consumed the invaded cells, they burst out again, and once more there is bedlam in the blood.

For the first time, the body realizes it has been ambushed. Headache and muscle pains are a sign that the immune system has been triggered. But if this is the victim's first bout of malaria, the immune response is mostly ineffective. The alarm has sounded, but the thieves are already under the bed: The parasites swiftly invade a new set of blood cells, and the sequence of reproduction and release continues.

Now the internal temperature begins to rise as the body attempts to cook away the invaders. Shivering sets in—muscle vibrations generate warmth. This is followed by severe fever, then drenching sweat. Cold, hot, wet; the symptoms are a hallmark of the disease. But the parasites' exponential growth continues, and after a few more cycles there are billions of them tumbling about the blood.

By this point, the fever has reached maximum intensity. The body is practically boiling itself to death—anything to halt the attack—but to no avail. The parasites can even commandeer blood cells to help aid their survival. In some cases of *falciparum,* infected cells sprout Velcro-like knobs on their surfaces, and as these cells pass through the capillaries of the brain, they latch to the sides. The adhesion keeps them from washing into the spleen, which cleans the blood by shredding damaged cells. Somehow—no one is quite sure how—the adhesion also causes the brain to swell. The infection has turned into cerebral malaria, the most feared manifestation of the disease.

This is when the body starts to break down. The parasites have destroyed so many oxygen-carrying red cells that too few are left to sustain vital functions. The lungs fight for breath, and the heart struggles to pump. The blood acidifies. Brain cells die. The child struggles and convulses and finally falls into a coma.

Malaria is a confounding disease—often, it seems, contradictory to logic. Curing almost all malaria cases can be worse than curing none. Destroying fragile wetlands, in the world of malaria, is a noble act. Rachel Carson, the environmental icon, is a villain; her three-letter devil, DDT, is a savior. Carrying a gene for an excruciating and often fatal blood disorder, sickle-cell anemia, is a blessing, for it confers partial resistance to *falciparum.* Leading researchers at a hundred medical centers are working on antimalarial medicines, but a medicinal plant described 1,700 years ago may be the best remedy available. "In its ability to adapt and survive," says Robert Gwadz, who has studied malaria at the National Institutes of Health, near Washington, D.C., for almost 35 years, "the malaria parasite is a genius. It's smarter than we are."

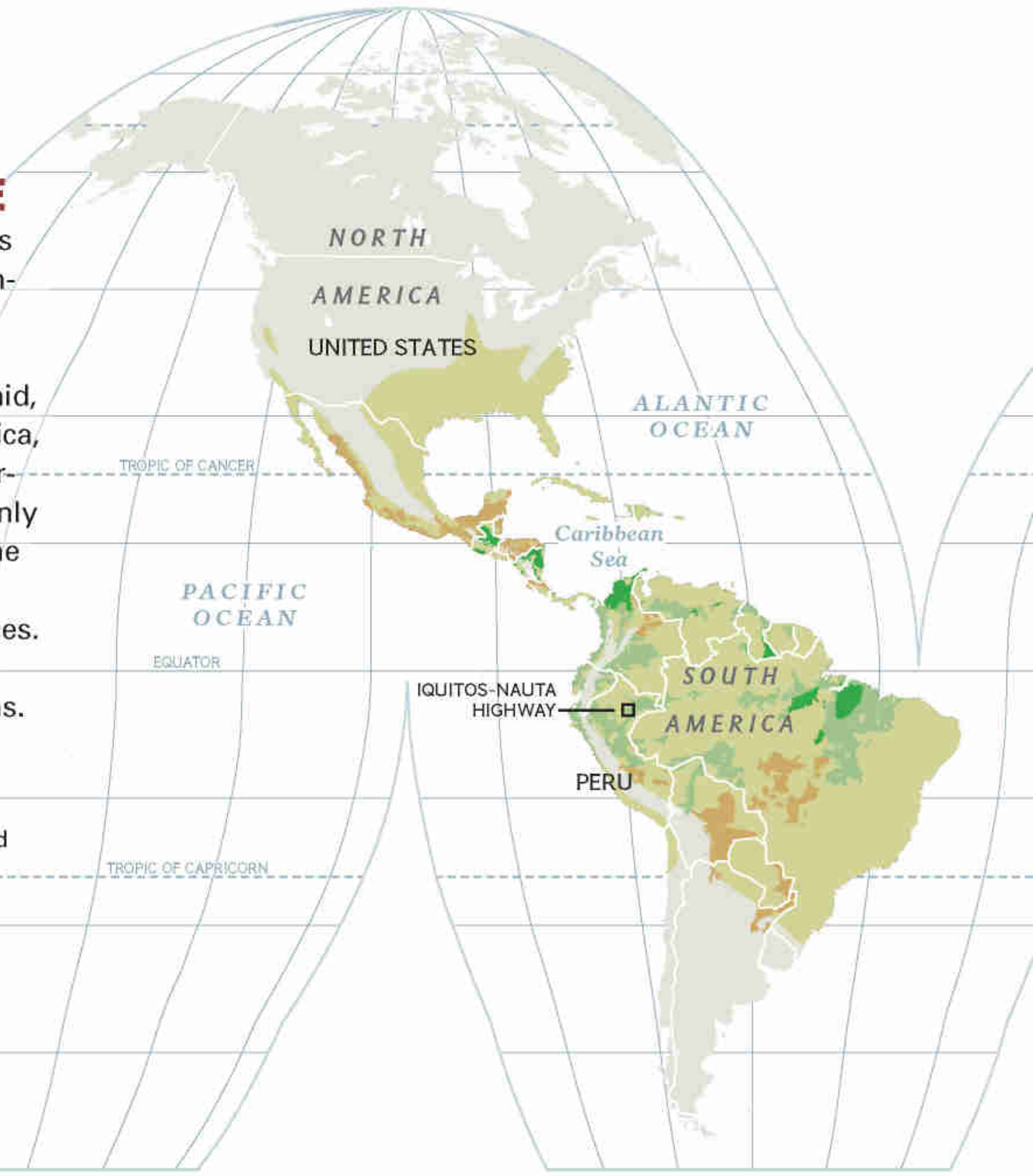
The disease has been with humans since before we were human. Our hominin ancestors almost certainly suffered from malaria. The parasite and the mosquito are both ancient creatures—the dinosaurs might have had malaria—and this longevity has allowed the disease ample time to exploit the vulnerabilities of an immune system. And not just ours. Mice, birds, porcupines, lemurs, monkeys, and apes catch their own forms of malaria. Bats and snakes and flying squirrels have malaria.

Few civilizations, in all of history, have escaped the disease. Some Egyptian mummies have signs of malaria. Hippocrates documented the distinct stages of the illness; Alexander the Great likely died of it, leading to the unraveling of the Greek Empire. Malaria may have stopped the armies of both Attila the Hun and Genghis Khan.

The disease's name comes from the Italian *mal'aria,* meaning "bad air"; in Rome, where malaria raged for centuries, it was commonly believed that swamp fumes produced the illness.

A GLOBAL BATTLE

Pushed out of temperate zones like southern Europe half a century ago by DDT spraying and draining of wetlands, malaria remains entrenched in the humid, lowland tropics of South America, Africa, and Asia. A less dangerous strain—*vivax*—occurs mainly in South America and Asia. The deadliest form—*falciparum*—sickens people in all three places. Sub-Saharan Africa suffers 90 percent of all malaria deaths.



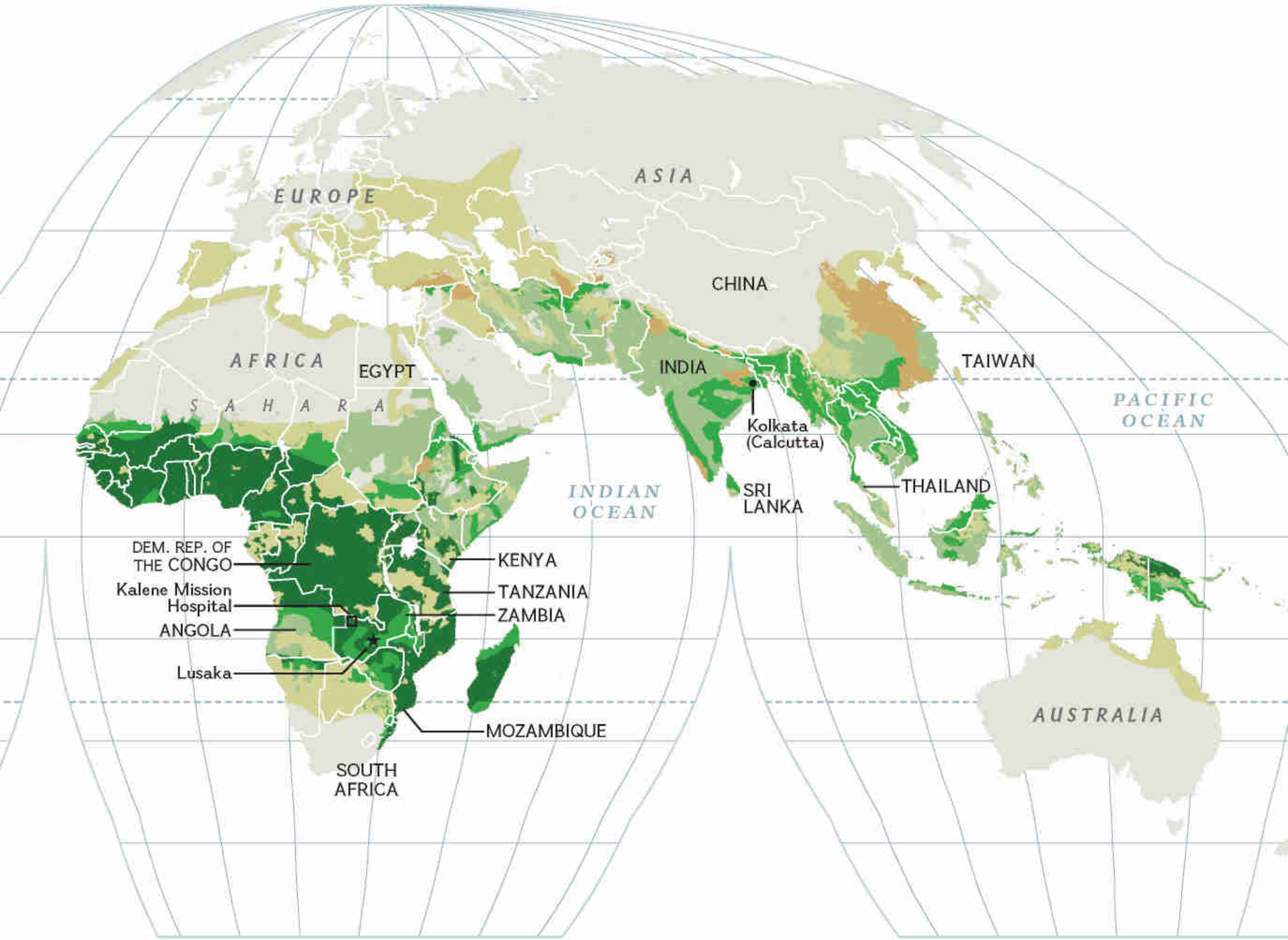
SOURCE : MALARIA ATLAS PROJECT
NGM MAPS; REPORTED BY HUGH K. TRUSLOW



SOUTH AMERICA A volunteer health worker listens for signs of respiratory trouble in a man complaining of aches and a high fever near Iquitos, in Peru's Amazon. A blood test showed malaria.



ASIA Suspecting malaria, a technician, right, at a Kolkata clinic draws blood in the very room where a century earlier Sir Ronald Ross (portrait on wall) discovered that mosquitoes spread the illness.







AFRICA After long walks from remote towns, parents at Zambia's Kalene Mission Hospital wait to find out whether their children have malaria. On average, more than half test positive.

At least four popes died of it. It may have killed Dante, the Italian poet. George Washington suffered from malaria, as did Abraham Lincoln and Ulysses S. Grant. In the late 1800s, malaria was so bad in Washington, D.C., that one prominent physician lobbied—unsuccessfully—to erect a gigantic wire screen around the city. A million Union Army casualties in the U.S. Civil War are attributed to malaria, and in the Pacific theater of World War II casualties from the disease exceeded those from combat. Some scientists believe that one out of every two people who have ever lived have died of malaria.

The first widely known remedy was discovered in present-day Peru and Ecuador. It was the bark of the cinchona tree, a close cousin of coffee. Local people called the remedy *quina quina* (bark of barks)—and it was later distributed worldwide as quinine. Word of the medicine, spread by Jesuit missionaries, reached a malaria-ravaged Italy in 1632, and demand became overwhelming. Harvested by indigenous laborers and carried to the Pacific coast for shipment to Europe, the bark sold for a fortune.

Several expeditions were dispatched to bring seeds and saplings back to Europe. After arriving in South America, the quinine hunters endured a brutal trek through the snow-choked passes of the Andes and down into the cloud forests where the elusive tree grew. Many perished in the effort. And even if the quinine hunters didn't die, the plants almost always did. For 200 years, until the cinchona tree was finally established on plantations in India, Sri Lanka, and Java, the only way to acquire the cure was directly from South America.

Quinine, which disrupts the malaria parasites' reproduction, has saved countless lives, but it has drawbacks. It is short-acting, and if taken too frequently can cause serious side effects, including hearing loss. In the 1940s, however, came the first of two extraordinary breakthroughs: A synthetic malaria medicine was introduced. The compound was named chloroquine, and it was inexpensive, safe, and afforded complete, long-lasting protection against all forms of malaria. In other words, it was a miracle.

The second innovation was equally miraculous. Swiss chemist Paul Müller discovered the insecticidal power of a compound called dichloro-diphenyl-trichloroethane, better known as DDT. Müller was awarded the 1948 Nobel Prize in medicine for his discovery, for nothing in the history of insect control had ever worked like DDT. Microscopic amounts could kill mosquitoes for months, long enough to disrupt the cycle of malaria transmission. It lasted twice as long as the next best insecticide, and cost one-fourth as much.

Armed with the twin weapons of chloroquine and DDT, the World Health Organization in 1955 launched the Global Malaria Eradication Programme. The goal was to eliminate the disease within ten years. More than a billion dollars was spent. Tens of thousands of tons of DDT were applied each year to control mosquitoes. India, where malaria had long been a plague, hired 150,000 workers, full-time, to spray homes. Chloroquine was widely distributed. It was probably the most elaborate international health initiative ever undertaken.

The campaign was inspired by early successes in Brazil and the United States. The U.S. had recorded millions of malaria cases during the 1930s, mostly in southern states. Then an intensive antimalaria program was launched. More than three million acres of wetlands were drained, DDT was sprayed in hundreds of thousands of homes, and in 1946 the Centers for Disease Control was founded in Atlanta specifically to combat malaria.

America's affluence was a major asset. Almost everyone could get to a doctor; windows could be screened; resources were available to bulldoze mosquito-breeding swamps. There's also the lucky fact that the country's two most common species of *Anopheles* mosquitoes prefer feeding on cattle rather than humans. By 1950, transmission of malaria was halted in the U.S.

The global eradication effort did achieve some notable successes. Malaria was virtually wiped out in much of the Caribbean and South Pacific, from the Balkans, from Taiwan. In Sri Lanka, there were 2.8 million cases of malaria in 1946, and a total of 17 in 1963. In India, malaria deaths

Settlers are flooding into the Amazon region of Peru along the new Iquitos-Nauta highway. In what was untouched rain forest, they farm fish (above), cut wood for charcoal (below)—and, increasingly, fall ill with malaria. As the trees fall, sunlight warms ponds and puddles, transforming them into mosquito breeding grounds. In little more than a decade, malaria cases in Peru's Amazon have risen from hundreds to more than 120,000 a year.

PERU | MAN-MADE MALARIA







Wood bakes into charcoal in a kiln near Peru's Iquitos-Nauta highway. Teodosia Borday and Carlos Solsol earn enough selling the charcoal to support a large family. Both have had malaria many times in a region where the disease was once rare.

plummeted from 800,000 a year to scarcely any.

But it was also clear that the campaign was far too ambitious. In much of the deep tropics malaria persisted stubbornly. Financing for the effort eventually withered, and the eradication program was abandoned in 1969. In many nations, this coincided with a decrease in foreign aid, with political instability and burgeoning poverty, and with overburdened public health services.

In several places where malaria had been on the brink of extinction, including both Sri Lanka and India, the disease came roaring back. And in much of sub-Saharan Africa, malaria eradication never really got started. The WHO program largely bypassed the continent, and smaller scale efforts made little headway.

Soon after the program collapsed, mosquito control lost access to its crucial tool, DDT. The problem was overuse—not by malaria fighters but by farmers, especially cotton growers, trying to protect their crops. The spray was so cheap

The U.S. had recorded millions of malaria cases in the 1930s. By 1950, transmission of malaria had been halted.

that many times the necessary doses were sometimes applied. The insecticide accumulated in the soil and tainted watercourses. Though nontoxic to humans, DDT harmed peregrine falcons, sea lions, and salmon. In 1962 Rachel Carson published *Silent Spring*, documenting this abuse and painting so damning a picture that the chemical was eventually outlawed by most of the world for agricultural use. Exceptions were made for malaria control, but DDT became nearly impossible to procure. "The ban on DDT," says Gwadz of the National Institutes of Health, "may have killed 20 million children."

Then came the biggest crisis of all: widespread drug resistance. Malaria parasites reproduce so quickly that they evolve on fast-forward, constantly spinning out new mutations. Some mutations protected the parasites from chloroquine. The trait was swiftly passed to the next generation of parasites, and with each new exposure to chloroquine the drug-resistant parasites multiplied. Soon they were unleashing large-scale malaria epidemics for which treatment could be exceedingly difficult. By the 1990s, malaria afflicted a greater number of people, and was harder to cure, than ever.

The story of malaria is currently being written—by hand, in ballpoint pen—by the staff of Zambia's Kalene Mission Hospital. Every morning, soon after dawn, a nurse's aide who has just finished the night shift records a brief update on each child in the intensive care ward. The report is written on lined notebook paper and clipped into a weathered three-ring binder. The day workers add frequent notations on the small patient cards, kept at the nurses' station. Together, the night report and the cards form a compelling, immediate account of a deadly disease.

Many entries are simply terse, staccato jottings. "Mary: Has malaria. Unconscious." "Belinda: Malaria. Seizures." But others are far longer, enumerating clinical details about medicines and dosages and checkup times, as well as offering vivid glimpses into the struggle for survival in one of the world's most malarious places. Leaf the pages; flip through the cards —there are thousands upon thousands of entries—and the stories emerge.

Here's Methyline Kumafumbo, a skinny three-year-old who was taken to Kalene hospital by her grandmother. They journeyed ten miles from their home village, and by the time they arrived, malaria parasites had already latched onto Methyline's brain. "Admitted yesterday," the night report reads. "Fevers and seizures. Malaria." The right side of Methyline's head was shaved, and an IV line inserted. Quinine, which remains Kalene hospital's frontline drug for severe cases, was administered, dose after dose, each treatment dutifully recorded.

For almost a week, Methyline languished in a coma. A malarial coma can be a horrible thing to observe: arched back, rigid arms, twisted hands, pointed toes. A still life of agony. The

Launderers do wash for Kolkata businesses in a pond's rocky shallows, one of many places in the city where malarial mosquitoes breed. Residents who lack faucets keep water in open buckets and barrels, where the insects multiply. A nozzle wielded by a city worker squirts pesticide into a gutter to kill larvae (below), a procedure so common that a mother hardly notices.

INDIA | URBAN BREEDING GROUND





Down with malaria, blacksmith Kashi Songkar (right) spends days laid up in his cramped Kolkata home. His wife (left) and father (on floor) have both been struck by the disease, which keeps students out of school and people home from jobs, eroding incomes.

reports continue their unblinking assessment. "Unconscious. Continues on IV quinine." "Still unconscious though not seizuring." "Still unconscious."

Then the seizures started again. There are times when the night report reads almost like a personal diary. "I was worried," the aide wrote about Methyline. "So I informed Sister"—the honorific bestowed on the hospital's two nurses—"who came and ordered Valium, which was given with relief."

Finally, the entries turn hopeful. "She's opening up her eyes but she still looks cerebral." "Drinking and eating porridge." And then: "Is conscious and talking!!" Three days later, Methyline was released from the hospital. "Looking bright," says the report. "But still not walking well."

One insidious thing about malaria is that many who don't die end up scarred for life. "Her walking issues point to larger problems," Robert Gwadz says after reviewing the progression of Methyline's sickness. "She may have permanent neurological damage." This legacy of malaria has sobering repercussions for people and nations. "It's possible," says Gwadz, "that due to malaria, almost every child in Africa is in some way neurologically scarred."

And Methyline has to be considered one of the fortunate ones. The Kalene hospital night report is filled with heartbreak. Christabel: "The patient is in bad condition. Grunting and weary. Irregular breathing. Sister was informed. Midnight she collapsed and died. The body was taken home. May her soul Rest in Peace." There's an entry like this on nearly every page. Ronaldo: "Semi-conscious. IV for quinine. Seizure. Valium. Pain suppository. Fever. More pain suppository. At 0500 hrs, child had gasping respiration. Finally, child suddenly collapsed and died. His body was taken home."

All of Zambia, it seems—from the army to the Boy Scouts to local theater troupes—has been mobilized to stop malaria. In 1985, the nation's malaria-control budget was 30 thousand dollars. Now, supported with international grant money, it's more than 40 million. Posters have been hung throughout the country, informing people of malaria's causes and symptoms and stressing the importance of medical intervention. (The vast majority of the nation's malaria cases are never treated by professionals.) There are even Boy Scout merit badges for knowledge about malaria. Zambia's plan is to educate the public, then beat the disease through a three-pronged assault: drugs, sprays, and mosquito nets.

The country has dedicated itself to dispensing the newest malaria cure, which also happens to be based on one of the oldest—an herbal medicine derived from a weed related to sagebrush, sweet wormwood, called artemisia. This treatment was first described in a Chinese medical text written in the fourth century A.D. but seems to have been overlooked by the rest of the world until now. The new version, artemisinin, is as powerful as quinine with few of the side effects. It's the last remaining surefire malaria cure. Other drugs can still play a role in treatment, but the parasites have developed resistance to all of them, including quinine itself. To help reduce the odds that a mutation will also disarm artemisinin, derivatives of the drug are mixed with other compounds in an antimalarial barrage known as artemisinin-based combination therapy, or ACT.

Zambia is also purchasing enough insecticide to spray every house in several of the most malarious areas every year, just before the rainy season. It has already returned to DDT—though just for indoor use, in controlled quantities. In the face of the growing malaria toll, access to DDT is gradually becoming easier, and even the Sierra Club does not oppose limited spraying for malaria control. Finally, the Zambian government is distributing insecticide-treated bed nets to ward off mosquitoes during the night, when the malaria-carrying *Anopheles* almost always bite.

The plan sounds straightforward, but progress against malaria never comes easily. Many Zambians living far from hospitals depend on roadside stalls for medicines. There, ACTs can cost more than a dollar a dose—virtually unaffordable in a country where more than 70 percent

MOVING TARGET

The complex life cycle of the malaria parasite makes it difficult to fight with a vaccine. Research is targeting stages of the cycle in both human and mosquito hosts.

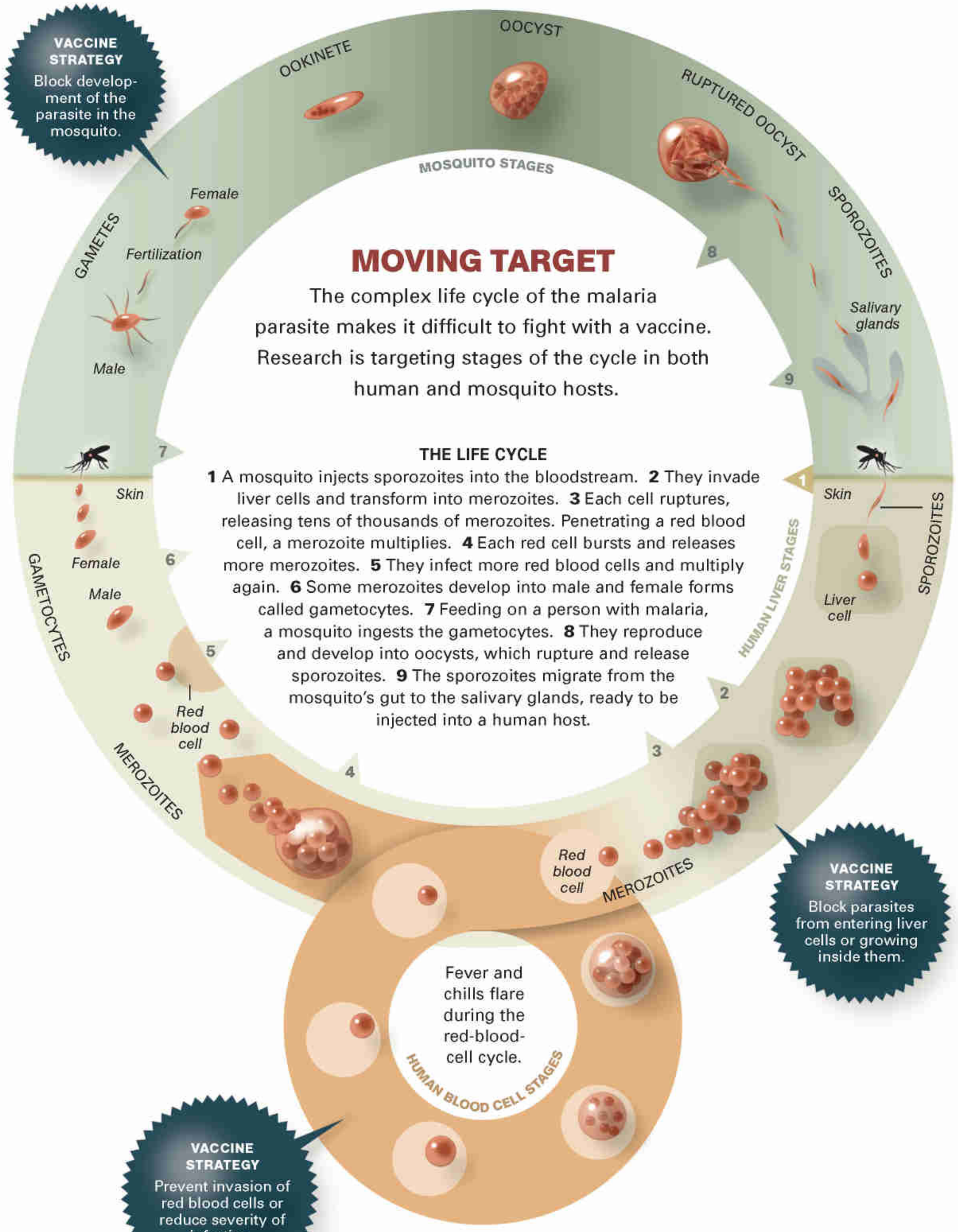
VACCINE STRATEGY
Block development of the parasite in the mosquito.

VACCINE STRATEGY
Block parasites from entering liver cells or growing inside them.

VACCINE STRATEGY
Prevent invasion of red blood cells or reduce severity of infection.

THE LIFE CYCLE

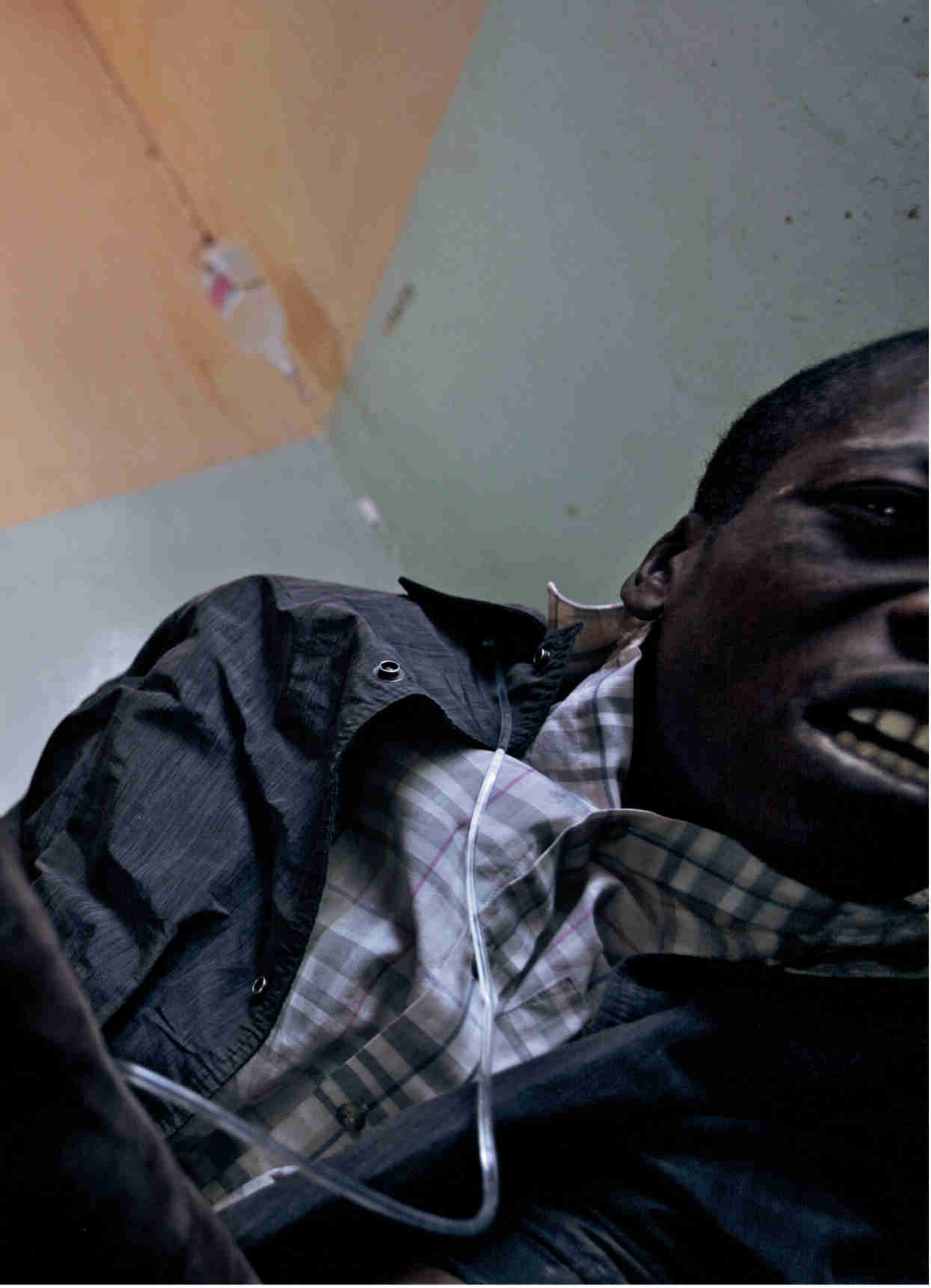
1 A mosquito injects sporozoites into the bloodstream. **2** They invade liver cells and transform into merozoites. **3** Each cell ruptures, releasing tens of thousands of merozoites. Penetrating a red blood cell, a merozoite multiplies. **4** Each red cell bursts and releases more merozoites. **5** They infect more red blood cells and multiply again. **6** Some merozoites develop into male and female forms called gametocytes. **7** Feeding on a person with malaria, a mosquito ingests the gametocytes. **8** They reproduce and develop into oocysts, which rupture and release sporozoites. **9** The sporozoites migrate from the mosquito's gut to the salivary glands, ready to be injected into a human host.



SOURCES: CENTERS FOR DISEASE CONTROL AND PREVENTION; MALARIA RESEARCH PROGRAM, WALTER REED ARMY INSTITUTE OF RESEARCH; PATH MALARIA VACCINE INITIATIVE

NGM ART; REPORTED BY HUGH K. TRUSLOW





Sick with severe malaria, Gideon Gori tosses feverishly in a Kenya hospital as a tube delivers quinine to kill the parasites. Untreated, Gori would have quickly died of complications from the disease, such as a steep drop in the red blood cells that carry oxygen through his body.

of the population survives on less than a dollar a day. So people buy other drugs, for as little as 15 cents. They provide temporary relief, reducing the malarial fever, but may do little to halt the parasites.

Then there are widespread traditional beliefs. One of the posters plastered across Zambia reads: "Malaria is not transmitted by witchcraft, drinking dirty water, getting soaked in rain, or chewing immature sugarcane." When children suffer from seizures—a symptom of advanced cerebral malaria—some parents interpret it as a hex and head straight to a traditional healer. By the time they make it to the hospital, it's too late.

Even the gift of a bed net can backfire. There's no question that the nets can save lives, especially the latest types, which are impregnated with insecticide. But first they need to reach the people most in need, and then they must be properly used. "Distributing nets to remote villages is a nightmare," says Malama Muleba, executive director of the nonprofit Zambia Malaria Foundation. "It's one thing for me to convince Bill and Melinda Gates to donate money, it's quite another to actually get the nets out."

In Zambia, a country that was steadily losing 50,000 children a year to malaria, early indications are that deaths have been cut by more than a third.

The Zambian army has been employed to help, but even after delivery, people can be reluctant to sleep beneath nets, which make a hot and stuffy part of the world feel hotter and stuffier. If a leg pops out at night or the fabric is torn, mosquitoes can still reach the skin. And the nets are sometimes misused, as fishing gear. Theater troupes are spreading out into the Zambian countryside, emphasizing the proper use of bed nets through stage productions in settlements large and small.

Despite the difficulties, Zambia's campaign has started to produce results. In 2000, a study showed that fewer than 2 percent of children under the age of five slept under an insecticide-treated bed net. Six years later, the number had risen to 23 percent. The government of Zambia says an ACT known as Coartem is now available cost free to the entire population. In a country that was steadily losing 50,000 children a year to malaria, early indications are that the death rate has already been reduced by more than a third.

But what if donor money dries up? What if Zambia's economy collapses? What about political instability? Both Angola and the Democratic Republic of the Congo, which flank Zambia, have a history of war. In the 1970s, during a civil war in Angola, six bombs landed near Kalene Mission Hospital; in the Congo war years, some of the nearby roads were mined.

"This is a critical moment," says Kent Campbell, program director of the Malaria Control and Evaluation Partnership in Africa. "There are no national models of success with malaria control in Africa. None. All we've seen is pessimism and failure. If Zambia is a success, it will have a domino effect. If it's a failure, donors will be discouraged and move on, and the problem will continue to get worse."

No matter how much time, money, and energy are expended on the effort, there still remains the most implacable of foes—biology itself. ACTs are potent, but malaria experts fear that resistance may eventually develop, depriving doctors of their best tool. Before the ban on DDT, there were already scattered reports of *Anopheles* mosquitoes resistant to the insecticide; with its return, there are sure to be more. Meanwhile, global warming may be allowing the insects to colonize higher altitudes and farther latitudes.

Drugs, sprays, and nets, it appears, will never be more than part of the solution. What's required is an even more decisive weapon. "When I look at the whole malaria situation," says Louis Miller, co-chief of the malaria unit at the National Institute of Allergy and Infectious Diseases, "it all seems to come down to one basic idea: We sure need a vaccine."

Many Africans suffering from malaria visit traditional healers, who can relieve symptoms. In Zambia, Selina Tembo (above, at right) gave a patient herbs that eased her pain and fever, allowing her to walk again. Sprayers in Zambia hit the disease at its source, applying a film of DDT inside mud houses. The insecticide lingers for months, repelling and killing mosquitoes.

AFRICA | A FIGHTING CHANCE







Recovering from malaria in Zambia's Kalene Mission Hospital, these children survived because their parents sought medical care fast—and found it nearby. Until they build up immunity through repeated infections, children with malaria are at higher risk of dying.

It's easy to list every vaccine that can prevent a parasitic disease in humans. There is none. Vaccines exist for bacteria and viruses, but these are comparatively simple organisms. The polio virus, for example, consists of exactly 11 genes. *Plasmodium falciparum* has more than 5,000. It's this complexity, combined with the malaria parasite's constant motion—dodging like a fugitive from the mosquito to the human bloodstream to the liver to the red blood cells—that makes a vaccine fiendishly difficult to design.

Ideally, a malaria vaccine would provide lifelong protection. A lull in malaria transmission could cause many people to lose any immunity they have built up against the disease—even adults, immunologically speaking, could revert to infant status—rendering it more devastating if it returned. This is why a partial victory over malaria could be worse than total failure. *Falciparum* also has countless substrains (each river valley seems to have its own type), and a vaccine has to block them all. And of course the vaccine can leave no opening for the parasite to develop resistance. Creating a malaria vaccine is one of the most ambitious medical quests of all time.

Recent malaria history is fraught with grand pronouncements that turned out to be baseless. "MALARIA VACCINE IS NEAR," announced a *New York Times* headline in 1984. "This is the last major hurdle," said one U.S. scientist quoted in the article. "There is no question now that we will have a vaccine. The rest is fine-tuning." Seven years of fine-tuning later, another *Times* headline summarized the result: "EFFORT TO FIGHT MALARIA APPEARS TO HAVE FAILED." In the late 1990s, Colombian immunologist Manuel Patarroyo claimed, with much media fanfare, that he had found the answer to malaria with his vaccine, SPf-66. Early results were tantalizing, but follow-up studies in Thailand showed it worked no better than a placebo.

At least 90 teams around the world are now working on some aspect of a vaccine; the British government, by way of incentive, has pledged to help purchase hundreds of millions of doses of any successful vaccine, for donation to countries in need. The one closest to public release, developed by the pharmaceutical company GlaxoSmithKline Biologicals in collaboration with the U.S. Army, is called RTS,S. In a recent trial in Mozambique, it protected about half the inoculated children from severe malaria for more than a year.

Fifty percent isn't bad—RTS,S might save hundreds of thousands of lives—but it's not the magic bullet that would neutralize the disease once and for all. Many researchers suspect an all-encompassing cure isn't possible. Malaria has always afflicted us, they say, and always will. There is one man, however, who not only believes malaria can be defeated, he thinks he knows the key.

Stephen Hoffman is the founder and CEO of the only company in the world dedicated solely to finding a malaria vaccine. The company's name is Sanaria—that is, "healthy air," the opposite of malaria. Hoffman is 58, lean and green-eyed, with a demeanor of single-minded intensity. "He's impassioned and impatient and intolerant of negativity," is how one colleague describes him.

Hoffman is intimately familiar with the pitfalls of the vaccine hunt. During his 14-year tenure as director of the malaria program at the Naval Medical Research Center, he was part of the team working on the vaccine promised in the 1984 *New York Times* article. He was so confident in the vaccine that he tested it on himself. He exposed himself to infected mosquitoes, then flew to a medical conference in California to deliver what he thought would be a triumphant presentation. The morning after he landed, he was already shaking and feverish—and, soon enough, suffering from full-blown malaria.

Now, more than two decades later, Hoffman is ready to return to prominence. He couldn't have found a more uninspiring launchpad: Sanaria is headquartered in a dismal mini-mall in suburban Maryland, near a picture-framing shop and a discount office-supply store. From outside, there's no mention of the company's



HOW DDT HELPED CURB AN EPIDEMIC

Three provinces in South Africa became a case study in how drug and pesticide resistance, weather, political turmoil, and HIV/AIDS can accelerate malaria. Cases rose in the mid-1980s when refugees arrived with the disease, then spiked in the late 1990s, especially after DDT use ended in 1996. Renewed DDT spraying in 2000 and new drugs helped turn the tide.

SOURCES: SOUTH AFRICAN MEDICAL RESEARCH COUNCIL (CASES); SOUTH AFRICA NATIONAL DEPARTMENT OF HEALTH; RICHARD TREN, AFRICA FIGHTING MALARIA

NGM ART; REPORTED BY HUGH K. TRUSLOW





A masked performer in Tanzania plays a malaria victim in an educational drama. His message: Use insecticidal bed nets all year. Only 2 percent of young children in Africa do. The cost—several dollars—discourages some families; others stop using nets as the rains end.



In the highlands of Tanzania, a Wa-arusha man harvests the Chinese herb *Artemisia annua*—a new crop in Africa and an ingredient in today's best malaria drugs. So far, the parasite has not developed resistance to it, buying time in the desperate fight against the disease.

mission. A window badly in need of washing bears the company name in tiny adhesive letters. Hoffman realizes it's probably best if the office-supply customers aren't fully aware of what's going on a few doors away.

Inside, generating a hubbub of activity, are some 30 scientists from across the globe. The lab's centerpiece is a room where Hoffman raises mosquitoes infected with the *falciparum* parasite—yes, in a quiet mini-mall. Hoffman claims it's the world's most secure insectary. To enter, a visitor must pass through multiple antechambers that are sealed between sets of doors, like a lock system in a canal. Everyone has to wear white cotton overlayers, masks, shoe covers, and gloves. White makes it easier to see a stray mosquito. The air is recirculated, and the insectary is checked daily for leaks. Signs abound: "WARNING! WARNING! INFECTIOUS AGENT IN USE." And hanging on a wall is a time-honored last line of defense: a flyswatter.

The mosquitoes are housed in a few dozen cylindrical containers, about the size of beach



buckets, covered with mesh lids. They're fed *falciparum*-infected blood, then stored for two weeks while the parasites propagate in the insects' guts and migrate to the salivary glands, creating what are known as "loaded" mosquitoes. The loaded insects are transferred carefully to a kiln-like irradiator to be zapped with a quick dose of radiation. Then, in a special dissecting lab, the salivary glands of the mosquitoes are removed. Each mosquito's glands contain more than 100,000 parasites. Essentially, the vaccine consists of these irradiated parasites packed into a hypodermic needle.

The idea is based on research done in the late 1960s at New York University by Ruth Nussenzweig, who demonstrated that parasites weakened by radiation can prompt an immune response in mice without causing malaria. Hoffman's vaccine will deliver the wallop of a thousand mosquito bites and, he says, produce a complete protective response. Thereafter, any time the vaccinated person is bitten by a malaria-carrying mosquito, the body, already in a state of alert, will not allow the disease to take hold.

Hoffman's lofty goal is to eventually immunize all 25 million infants born in sub-Saharan Africa every year. He believes that at least 90 percent of them will be protected completely from malaria. If so, they'll be the first generation of Africans, in all of human history, not to suffer from the disease.

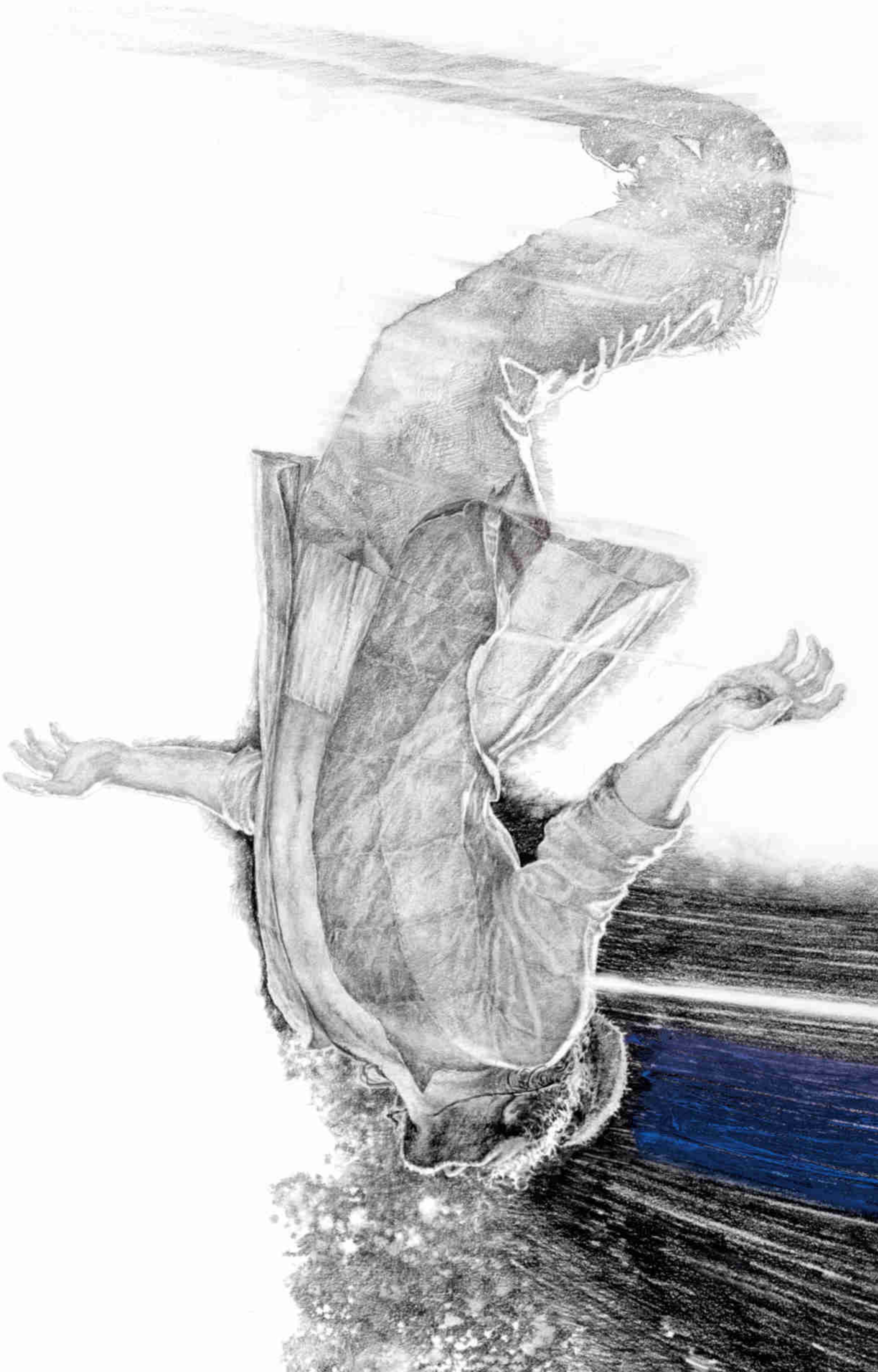
But which generation will it be? Although Sanaria's vaccine may undergo initial field-testing next year, a federally approved version won't be available for at least five years—and maybe never. Given the track record of malaria vaccines, that's a distinct possibility. After so many million years on Earth and so many victories over humanity, the disease, it is certain, will not surrender easily.

When it comes to malaria, only one thing is guaranteed: Every evening in the rainy season across much of the world, *Anopheles* mosquitoes will take wing, alert to the odors and warmth of living bodies. A female *Anopheles* needs to drink blood every three days. In a single feeding, which lasts as long as ten minutes, she can ingest about two and a half times her pre-meal weight—in human terms, the equivalent of downing a bathtub-size milk shake.

If she happens to feed on a person infected with malaria, parasites will accompany the blood. Two weeks later, when the mosquito flies through the open window of a mud hut, seeking her next meal, she'll be loaded.

Inside the hut, a child is sleeping with her sister and parents on a blanket spread over the floor. The family is aware of the malaria threat; they know of the rainy season's dangers. They've hung a bed net from the ceiling. But it's a steamy night, and the child has tossed and turned a few times before dropping back to sleep. Her foot is sticking out of the net. The mosquito senses it, and dips down for a silent landing. □

Worldwide War Listen to photographer John Stanmeyer, who shares his thoughts on the impact of this deadly disease at **ngm.com/0707.**



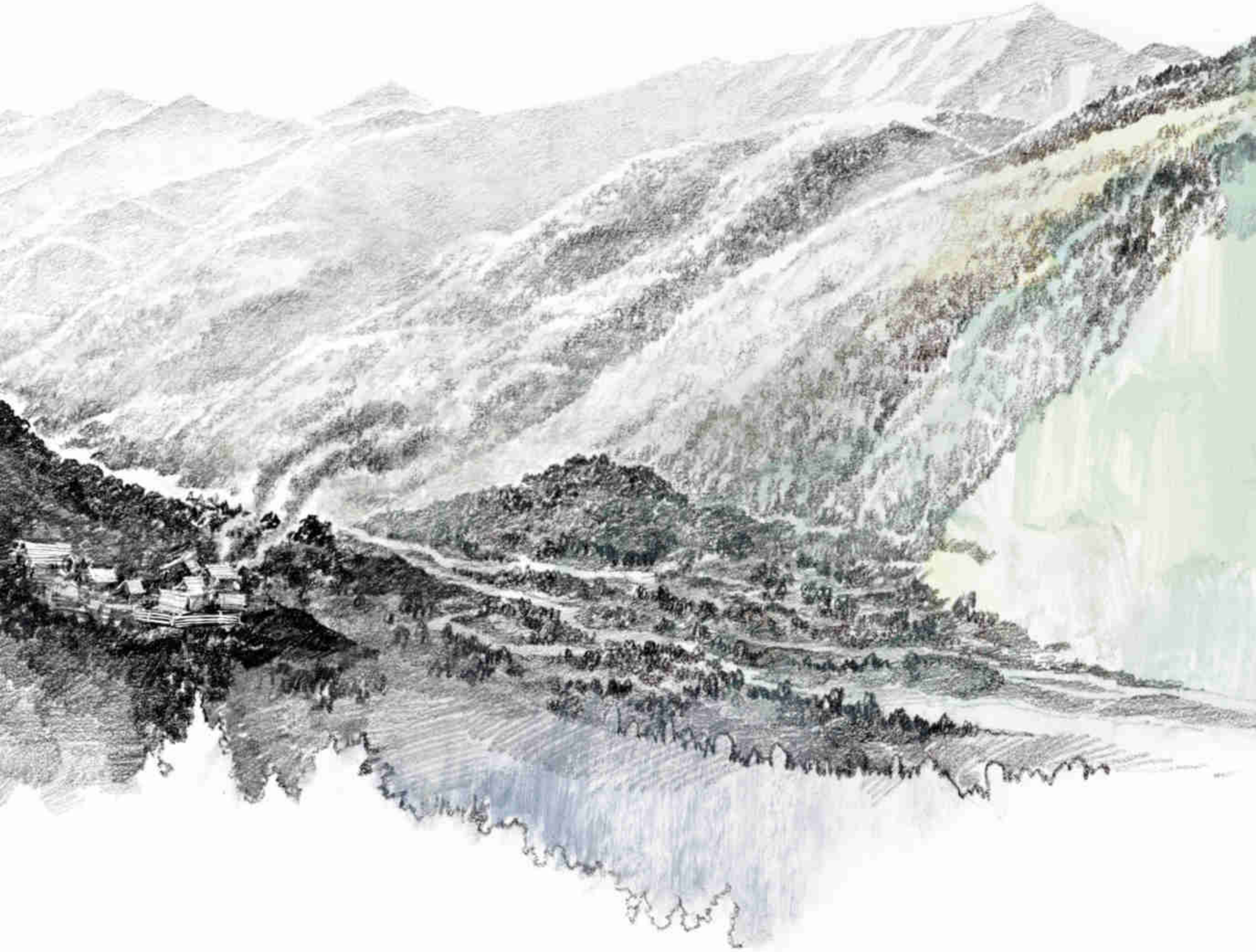
Last Hours of the Iceman

In 1991 the frozen body of a man who lived 5,300 years ago emerged from a melting glacier in the Alps. New forensic evidence reveals that he was killed by an arrow to the back, possibly during an ambush.



By Stephen S. Hall
Art by Kazuhiko Sano

It was late spring or early summer, when a modest tree called the hop hornbeam unfurls bright yellow clusters of flowers in the steep valleys that run north into the mountains now known as the Italian Alps. The man hurried through a forest he knew well, wincing from the pain in his injured right hand and pausing occasionally to listen for sounds that he was being pursued. As he fled up the slope, the yellow pollen of the hornbeam blossoms fell like an invisible rain, salting the water and food he consumed when he stopped to rest. Five thousand years later, the Neolithic hunter we call the Iceman would still bear traces of this ancient dusting inside his body—a microscopic record of the time of year it was when he passed through this forest and into the nearby mountains, where fate would finally catch up with him.



Since hikers discovered his mummified corpse in 1991 in a rocky hollow high in the Ötztal Alps on Italy's border with Austria, scientists have used ever more sophisticated tools and intellectual cunning to reconstruct the life and times of the Iceman (or "Ötzi"), the oldest intact member of the human family. We know that he was a small, sinewy, and, for his times, rather elderly man in his mid-40s. Judging from the precious, copper-bladed ax found with him, we suspect that he was a person of considerable social significance. He set off on his journey wearing three layers of garments and sturdy shoes with bearskin soles. He was well equipped with a flint-tipped dagger, a little fire-starting kit, and a birchbark container holding embers wrapped in maple leaves. Yet he also headed into a harsh wilderness curiously under-armed: The arrows in his deerskin quiver were only half finished, as if he had recently fired all his munitions and was in the process of hastily replenishing them. And he was traveling with a long, roughly shaped stalk of yew—an unfinished longbow, yet to be notched and strung. Why? *(Continued on page 76)*

Days before he died, the Iceman suffered cuts to his right hand and wrist—the kind a hatchet would make. In his mid-40s, he was an elder in his village and likely a leader, judging from his fine copper ax. Younger rivals may have picked a fight, hoping to topple him from power.



THE SCIENCE BEHIND THE ICEMAN

The world's best studied mummy holds clues to life in the Stone Age—and maybe a lethal rivalry.



Missing his hair, toenails, all but one fingernail, and an outer layer of skin, the Iceman is otherwise perfectly preserved. Scientists have examined him exhaustively and now believe they know how he died. An arrow, similar to those in his own quiver (left), pierced his back and severed an artery. Someone—likely his killer—pulled out the arrow's shaft and left him to bleed to death. A CT scan (right) shows the arrowhead still embedded below his left shoulder.





SOUTH TYROL MUSEUM OF ARCHAEOLOGY, BOLZANO, ITALY (ARROWS); PAUL GOSTNER, SOUTH TYROL MUSEUM OF ARCHAEOLOGY, CENTRAL HOSPITAL OF BOLZANO (CT SCAN); HEINER MÜLLER-ELSNER, SOUTH TYROL MUSEUM OF ARCHAEOLOGY (EXAMINING TABLE)



Hurriedly equipped with survival gear, the Iceman began to climb a forested path, first passing hop hornbeams and then pines. These trees left pollen on his food, a clue from his intestines that suggests he doubled back before heading to the peak, as if trying to evade enemies in pursuit.

When it comes to the Iceman, there has never been a shortage of questions, or theories to answer them. During the 16 years that scientists have poked, prodded, incised, and x-rayed his body, they have dressed him up in speculations that have not worn nearly as well as his rustic garments. At one time or another, he has been mistakenly described as a lost shepherd, a shaman, a victim of ritual sacrifice, and even a vegan. But all these theories fade in the face of the most startling new fact scientists have learned about the Iceman. Although we still don't know exactly what happened up there on that alpine ridge, we now know that he was murdered, and died very quickly, in the rocky hollow where his body was found.

"Even five years ago, the story was that he fled up there and walked around in the snow and probably died of exposure," said Klaus Oeggl, an archaeobotanist at the University of Innsbruck. "Now it's all changed. It's more like a paleo crime scene."

This is a story of scientific insight brought to bear on the skimpiest of clues to reconstruct a riveting scene of Neolithic noir.

THE OBJECT OF ALL THIS intense scientific attention is a freeze-dried slab of human jerky, which since 1998 has resided in a refrigerated, high-tech chamber in the South Tyrol Museum of Archaeology in Bolzano, Italy. The temptation to conduct fresh experiments on the body rises with every new twist of technology, each revealing uncannily precise details about his life. Using a sophisticated analysis of isotopes in one of the Iceman's teeth, for example, scientists led by Wolfgang Müller (now at the Royal Holloway, University of London) have shown that he probably grew up in the Valle Isarco, an extensive north-south valley that includes the modern-day town of Bressanone. Isotope levels in his bones, meanwhile, match those in the soil and water of two alpine valleys farther west, the Val Senales and the Val Venosta. Müller's team has also analyzed microscopic chips of mica recovered from the Iceman's intestines, which were probably ingested accidentally in food made from stone-ground grain; geologic ages of the mica best match a small area limited to the lower Val Venosta. The Iceman probably set off on his final journey from this very area, near where the modern-day Adige and Senales Rivers meet.

We also know that he was not in good health when he headed up into the mountains. The one surviving fingernail recovered from his remains suggests that he suffered three episodes of significant disease during the last six months of life, the last bout only two months prior to his death. Doctors inspecting the contents of his intestines have found eggs of the whipworm parasite, so he may well have suffered from stomach distress. But he was not too sick to eat.

In 2002, Franco Rollo and colleagues at the University of Camerino in Italy analyzed tiny amounts of food residue from the mummy's intestines. A day or two before his death, the Iceman had eaten a piece of wild goat and some plant food. The same analysis revealed that his very last meal was red deer and some cereals. The archaeobotanist Klaus Oeggl has concluded from bran-like food residues that the Iceman's diet also included the primitive form of wheat known as einkorn as well as barley, found on his garments, indicating that the Neolithic settlements south of the Alps where he lived cultivated these grains. Oeggl has even found that the small size of the wheat fragments in the gut, along with tiny flecks of charcoal, suggest that the grains were ground and then baked as primitive bread in open fires.

Archaeobotanists have used equally clever analyses of pollen and plant fragments to plot the

Stopping for a breather, the Iceman set down his gear and removed his grass cloak, which was found beside him. The spot was out of the wind, but the surrounding rocks offered many places to hide. His enemies—how many remains a mystery—sneaked up and shot him from behind.



Iceman's last movements. James Dickson of the University of Glasgow has identified no less than 80 distinct species of mosses and liverworts in, on, or near the Iceman's body. The most prominent moss, *Neckera complanata,* still grows at several sites in the valleys to the south, in some cases quite near known prehistoric sites. According to Dickson, a clot of stems found in the Iceman's possession suggests he was probably using the moss to wrap food, although other ancient peoples used similar mosses as toilet paper.

Taken together, the evidence strongly indicates that the Iceman's last journey began in the low-altitude deciduous forests to the south, in the springtime when the hop hornbeams were in bloom. But it may not have been a straight hike into the mountains. Oeggl has also found traces of pine pollen in the Iceman's digestive tract, both above and below the hornbeam pollen. This suggests that he may have climbed to a higher altitude where pine trees grow in mixed coniferous forests, then descended to the lower altitude of the hop hornbeams, and finally ascended again into the pine forests in his last day or two. Why? No one knows. But perhaps he wanted to avoid the steep, thickly wooded gorge of the lower Val Senales—especially if he was in a hurry.

When he reached a mountain pass now known as Tisenjoch, he likely paused to rest. He had completed a vertical climb of 6,500 feet from the valley below, and to the north faced a desolate, glacier-riven landscape. Perhaps the rocky hollow where he found himself offered some shelter from the wind. We do not know if his enemies caught up with him at that spot, or were waiting there in ambush for him to arrive. What we do know is that he never left that hollow alive.

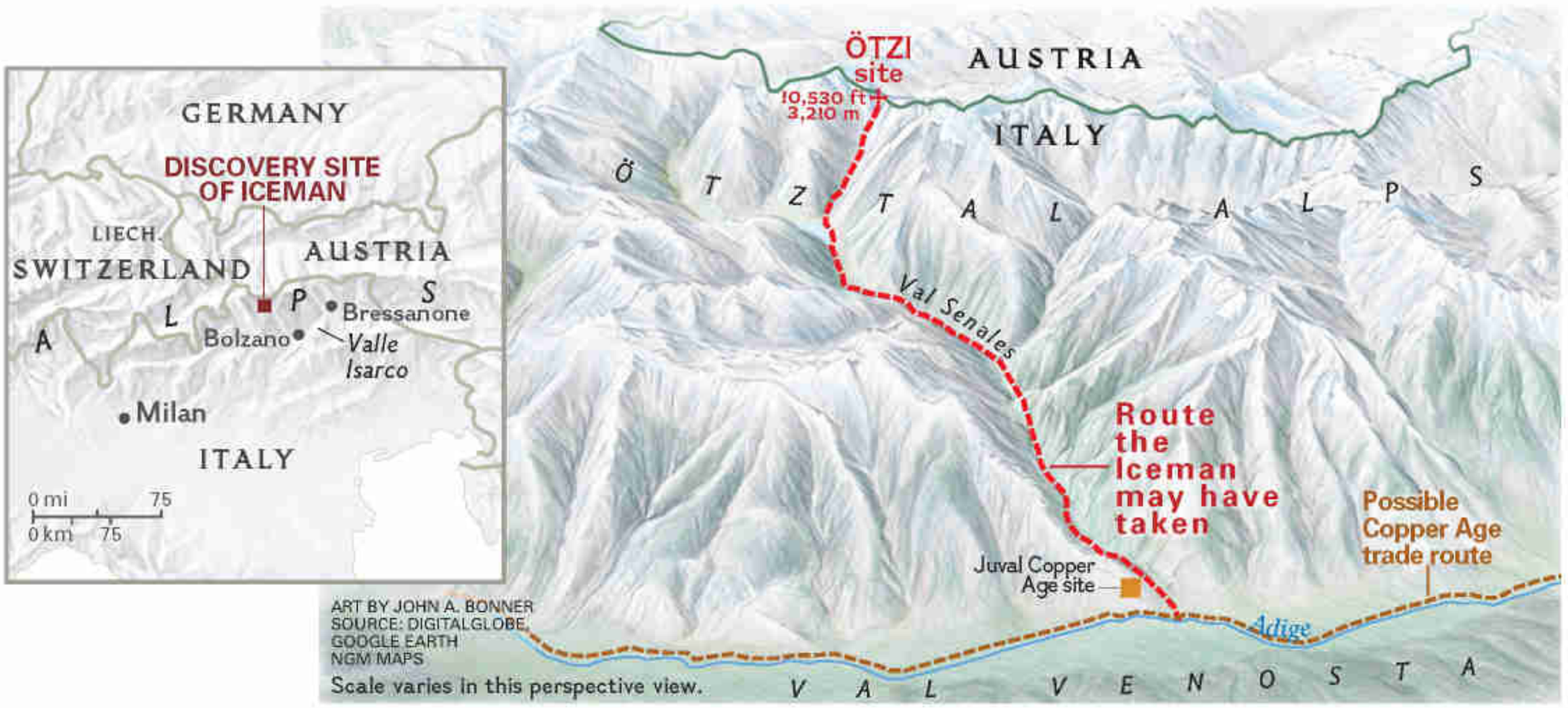
We now know that the Iceman was murdered, and died very quickly, in the same rocky hollow where his body was found.

IN JUNE 2001, Paul Gostner, director of the Department of Radiology at the Central Hospital in Bolzano, brought a portable x-ray machine to the Iceman's chamber. His intent was to prepare for a routine analysis of some broken ribs. The following day he dropped by the office of Eduard Egarter Vigl, director of the Institute of Pathology at the hospital and principal caretaker of the mummy, to report that the rib fractures were old and of limited interest.

"But I've found another thing that I can't explain," he said. "There is this strange extraneous object in the left shoulder." When he compared his recent x-rays (and CT scans taken three months earlier) of the Iceman's torso with earlier films taken by scientists in Innsbruck, Gostner managed to detect what his Austrian colleagues had missed: a dense triangular shadow smaller than a quarter and lodged beneath the Iceman's left shoulder blade. It turned out to be a stone arrowhead. This "casual discovery," as Egarter Vigl put it, instantly turned an inexplicable death more than 5,000 years ago into archaeology's most fascinating cold case.

The forensic evidence became even more intriguing in 2005, shortly after the hospital in Bolzano acquired a new high-resolution multi-slice CT scanning machine. Gostner, Egarter Vigl, Patrizia Pernter, a physician in the Department of Radiology, and Frank Rühli, a doctor and senior lecturer in anatomy at the University of Zürich, decided to take a closer look at the body with the new CT machine. In August 2005, doctors placed the Iceman on a custom-built foam mattress, covered him with an insulated blanket and heaps of ice, and rushed him by ambulance (with a police escort) on the ten-minute ride from the museum to the hospital. There, with the kind of urgency usually reserved for humans in critical condition, they whisked the mummy into the scanning suite and quickly took a series of scans. "You had to do it before he thawed," Rühli noted, "so you had to hurry."

The results were astonishing. The sharpened piece of stone, probably flint, had made a half-inch gash in the Iceman's left subclavian artery. This is the main circulatory pipeline carrying fresh oxygenated blood from the pumping



chamber of the heart to the left arm. Such a serious tear in a major thoracic artery would almost certainly lead to uncontrolled bleeding and rapid death. "This is a lethal wound," Rühli says. "It was pretty quick. With this kind of bleeding, you don't go walking uphill for hours."

This new medical evidence suggests that an attacker, positioned behind and below his victim, fired a single arrow that struck the Iceman's left shoulder blade—precisely the area at which prehistoric hunters aimed to bring down game with one shot. The arrow went clean through the bone and pierced the artery. Blood instantly began to gush out, filling the space between the shoulder blade and the ribs. In his few remaining minutes of life, the Iceman became a textbook case of what is now known as hemorrhagic shock. His heart started to race. Sweat drenched his garments, even at an altitude two miles above sea level. He felt increasingly faint because not enough oxygen was reaching his brain. In a matter of a few minutes, the Iceman collapsed, lost consciousness, and bled out.

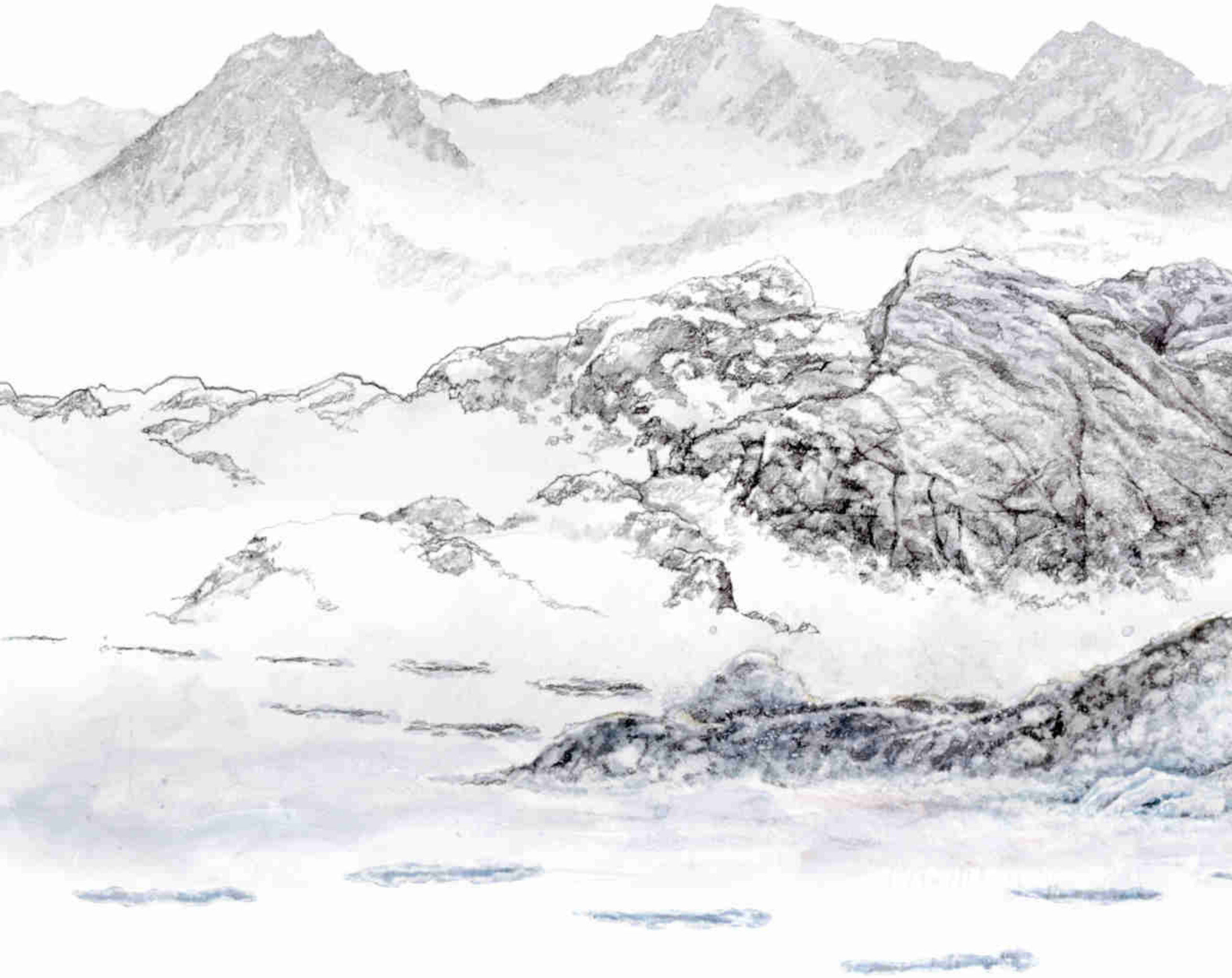
Then, in a fantastically fortunate cascade of circumstance, the brutal weather of the Ötztal Alps conspired with chance to perform one of the greatest embalming jobs in the history of human remains. The frigid glacial environment eventually tucked him in like a cold, wet blanket, immobilizing and preserving his body in snow, ice, and glacial meltwater. The little

The Iceman died at a pass in the Ötztal Alps—hence his nickname, "Ötzi." Trace elements in his teeth and bones reveal that he lived as an adult in the Val Venosta, some 12 miles to the south, and that he grew up nearby in the Valle Isarco.

ravine protected his lifeless form from the bone-grinding action of the Niederjoch Glacier, which passed just a few feet overhead for the next 5,300 years.

WHO KILLED THE ICEMAN, and why? Was this a Neolithic version of highwaymen ambushing a hunter and snatching his catch? Or was he stalked and killed by a person, or persons, who knew him? Experts now believe that the mystery may hinge on a bizarre detail of the crime scene. The shaft of the fatal arrow was nowhere to be found. Someone must have pulled it out, leaving behind the stone arrowhead lodged in his body.

"I believe—in fact, I am convinced—that the person who shot the Iceman with the arrow is the same person who pulled it out," says Egarter Vigl. In an article that appeared this May in the German archaeology magazine *Germania,* Egarter Vigl and his colleagues noted that telltale markings in the construction of prehistoric arrows could be used to identify the archer much in the way that modern-day ballistics



can link a bullet to a gun. They argue that the Iceman's killer yanked out the arrow shaft precisely to cover his tracks. For similar motives, Egarter Vigl reasons, the attacker did not run off with any of the precious artifacts that remained at the scene, especially the distinct copper-bladed ax; the appearance of such a remarkable object in the possession of a villager would automatically implicate its owner in the crime.

Other, more controversial research has suggested that this final mortal blow may have been preceded by fierce, hand-to-hand combat. The late Tom Loy, a molecular archaeologist at the University of Queensland in Australia, claimed in 2003 that human blood from no less than four separate individuals had been identified on the Iceman's garments and weapons. But Loy's research has been aired only in media accounts, and skeptics in the academic community say the claims are impossible to assess until they are published in the scientific literature.

Nonetheless, the idea that the Iceman was attacked by more than one person complements the "theory of the crime" proposed by Walter Leitner, an archaeologist at the University of Innsbruck who is an expert in both archery and Stone Age culture. He believes the bloody mountaintop confrontation was the denouement of a political dispute that began down in the valley, where rivals within the Iceman's own tribe tried to assassinate him. A microscopic analysis of the Iceman's hand wound, and the fact that it had begun to close and heal, suggests that it occurred well before the final mortal blow. "So there must have been some fight, some kind of battle, at least one day—and perhaps even



Perfect conditions—glacial meltwater, drying wind and sun, and blanketing snow and ice—preserved and mummified the Iceman's body, and the high ravine protected it as a glacier grew overhead. Exceptionally warm weather eventually melted the ice and allowed him to be found.

two or three days—earlier," said Egarter Vigl. "The time had come where his opponents had become stronger," Leitner speculates, "but he didn't recognize that his reign was coming to an end and was holding on to his position." Leitner says that after the fight in the village, "It looks as if the Iceman was planning to flee and that his trip was brought to an end by his opponents."

The previous, erroneous theories about the Iceman's demise remind us that much of the current speculation, while plausible, must stand up in the face of continuing research. Above all, this tale of an enigmatic and bloody death atop a desolate alpine ridge is a story about remarkable scientific insight brought to bear on the skimpiest of clues—a fingernail here, a milligram of food residue there, a few grains of pollen—in order to reconstruct a riveting scene of Neolithic noir. Although not a single grunt or cry has passed through the Iceman's mummified lips in more than 5,000 years, the ongoing investigation continues to tell us new and startling things about life—and death—in the Stone Age. □

Inside the Iceman Get an update on the life and death of this Neolithic hunter in an interactive exploration of his remains at **ngm.com/0707**.

Feathers of Seduction

For New Guinea's birds of paradise, attracting a mate is a performing art.

Framed by its wiry tail feathers, a red bird of paradise is nature's valentine—an apt emblem for this family of birds famous for fanciful plumage and elaborate courtship rituals.

PARADISAEA RUBRA







Flamboyant feathers draw female attention —and once made birds of paradise prime targets for plume hunters. The Goldie's bird (above) calls and displays with other males, while the blue bird of paradise (opposite) is a solo performer.

PARADISAEA RUDOLPHI; P. DECORA



The “ballerina dance” is one of at least six distinct moves in the repertoire of Carola’s parotia, which has the most complex courting ritual in the bird of paradise family. Females scrutinize his act from above.

PAROTIA CAROLAE

BY JENNIFER S. HOLLAND
NATIONAL GEOGRAPHIC STAFF
PHOTOGRAPHS BY TIM LAMAN

He bows.

His bend is deep and dignified even as his cape of velvet black feathers rises to expose pale flanks. Springy wires topping his head tap the ground, one, two, one, two. The showman's stage is a patch of earth that he's cleared of forest debris before scattering beakfuls of roots, like petals in a bride's path. His audience: a row of skeptical females fidgeting on an overhanging limb. Their attention is fleeting, so he launches into his routine, toeing forward on skinny legs like a ballerina en pointe. He pauses for dramatic effect, then moves into the jungle boogie. His neck sinks and his head bobs, head wires bouncing on the offbeat. He hops and shakes, wings flapping or tucked in, chin whiskers fluttering.

His performance has the desired effect. The nearest female quivers in invitation, and with a nasal blast the dancer jumps her. Feathered commotion blocks the view, and it's unclear whether the romp is successful. But no matter: Another show will begin soon.

Here in the sweaty, vine-tied jungle of New Guinea is nature's most absurd theater, the mating game of the birds of paradise. No other birds on Earth go about the business of breeding quite like these. To dazzle choosy females, males strut in costumes worthy of the stage: cropped capes, shiny breast shields, head ribbons, bonnets, beards, neck wattles, and wiry feathers that curl like handlebar mustaches. Their vivid reds, yellows, and blues blaze against the relentless green of the rain forest. What makes for the sexiest mix of costume and choreography is a mystery, but it seems the more extreme the better.

Birds of paradise perch on an improbable branch of the avian family tree, the flashy cousins of straitlaced ravens and crows. They began splitting off from their bland kin millions of years ago, evolving into today's 38 eclectic species. Of these, 34 live only on New Guinea and its satellite islands.

Some of the first specimens to reach Europe, offered by New Guineans as gifts to Western kings, arrived in Spain in 1522 aboard one of Magellan's ships. It was rumored that these extraordinary birds came from the heavenly realms, where they soared through paradise without wings and never touched the earth. (The legend may have originated in the fact that wings and feet were often trimmed from trade skins.) The sight of the birds in the wild amazed early travelers: "My gun remained idle in my hand as I was too astonished to shoot," admitted naturalist René Lesson, who visited New Guinea in 1824 and brought back the first eyewitness account. "It was like a meteor whose body, cutting through the air, leaves a long trail of light." Their names bespeak the wonder they inspired: superb bird, magnificent bird, splendid bird, emperor bird.

For decades Europe's appetite for their plumes fueled hunting and vigorous commerce. At the trade's peak in the early 1900s, some 80,000 skins a year were exported from New Guinea for ladies' hats. Birding groups in England and the United States raised the alarm, and the slaughter abated as a conservation ethic grew. In 1908 the British outlawed commercial hunting in parts of New Guinea *(Continued on page 94)*





Mist pools between mountain ridges in New Guinea's western highlands. Much of this equatorial island remains undeveloped and unexplored by outsiders. In 2005 scientists were surprised to encounter a bird of paradise species previously known only from a few dead specimens collected more than a century ago.



Trailing a streamer three times the length of its foot-long body, the ribbon-tailed astrapia boasts the longest tail of any bird. Such an encumbered bird would be easy prey in most places, but in New Guinea predators are few. Genetic innovations endure if they offer an advantage in luring a mate.

ASTRAPIA MAYERI





KING BIRD OF PARADISE, *CICINNURUS REGIUS*



WESTERN PAROTIA, *PAROTIA SEFILATA*



MAGNIFICENT BIRD OF PARADISE, *CICINNURUS MAGNIFICUS*



TWELVE-WIRED BIRD OF PARADISE, *SELEUCIDIS MELANOLEUCA*



New Guinea and its satellite islands are home to 34 species of birds of paradise. Australia hosts four species, the Moluccas two.

NGM MAPS



RED BIRD OF PARADISE, *PARADISAEA RUBRA*



STEPHANIE'S ASTRAPIA, *ASTRAPIA STEPHANIAE*

BIRDS OF PARADISE

Divided, They Diversified

Mountainous New Guinea is a tiered wedding cake of habitats. Most birds of paradise are habitat specialists that live within the bounds of a single mountain range and altitude zone. This isolation reduces the flow of genes between populations, allowing the birds to diverge into the strange and beautiful (gallery, above).

All birds of paradise descend from crow-like ancestors, but only manucodes still look the part. Males and females are nearly identical and likely monogamous, unlike their flashy, flirtatious kin.

MANUCODIA COMRII



under their rule, and the Dutch followed suit in 1931. Today no birds of paradise leave the island legally except for scientific use.

The indigenous people of New Guinea revered the birds long before outsiders paid heed. The finest plumes were used as bride price, and the birds figure prominently in local myths as ancestors and clan totems. They are revered still. "We love these birds," says a lowland tribesman. "The people of my family *are* birds of paradise."

Anthropologist Gillian Gillison of the University of Toronto lived among New Guinea tribes for more than a decade. She points to a myth in which a girl places her brother's lifeless body in a hollow tree. She strikes the tree, and birds of paradise explode upward like smoke and downward like fire. The smoke represents dark, highland birds, the fire vivid, lowland species. "To local people, the feathers are related to the spirit flying," she says. "They also symbolize a birth. They're the origin of the world."

With their glam attire and sexual theatrics, birds of paradise also embody a biological mystery: Why would evolution, with its pitiless accounting of cost and benefit, tolerate such ostentation, much less give rise to it? After all, exhibitionism is expensive, in biological terms, and a red flag to predators.

"Here in New Guinea it isn't nature tooth and claw, but nature with painted skirt and crowned brow—a bird drag show," says biologist Ed Scholes of New York's Museum of Natural History. "Life here is pretty comfortable for birds of paradise. The island's unique environment has allowed them to go to extremes unheard of elsewhere." Under harsher conditions, he says, "evolution simply wouldn't have come up with these birds."

Fruit and insects abound all year in the forests of New Guinea, the largest tropical island in the world, and natural threats are few. Linked to Australia until about 8,000 years ago, the 1,500-mile-long island shared much of its neighbor's fauna. Marsupials and birds were plentiful, but placental mammals were entirely absent, meaning no monkeys and squirrels to compete with birds for food, and no cats to prey on them. The result: an avian paradise that today is home to more than 700 species of birds.

Freed of other pressures, birds of paradise began to specialize for sexual competition. Traits that made one bird more attractive than another were passed on and enhanced over time. Known as sexual selection, this process "is to birds of paradise what natural selection is to Darwin's finches—the prime mover," says Scholes. "The usual rules of survival aren't as important here as the rules of successful mating."

"Here in New Guinea it isn't nature tooth and claw, but nature with painted skirt and crowned brow—a bird drag show. The island's unique environment has allowed them to go to extremes unheard of elsewhere." —ED SCHOLES

BIOLOGIST, MUSEUM OF NATURAL HISTORY, NEW YORK

The diversity of New Guinea's birdlife also springs from its wealth of habitats, from humid coastal savannas to high-elevation cloud forests. Tangled swamps checker the lowlands, while a spine of rugged mountains, some rising 16,000 feet, creates a labyrinth of scarp and crag in the remote interior. Shaped by volcanoes, earthquakes, and equatorial rains, the landscape is rife with physical barriers that isolate wildlife populations, allowing them to diverge into new species. (The fractured landscape is also reflected in the diversity of indigenous cultures; more than 750 languages are spoken just in Papua New Guinea, the eastern half of the island.)

Much of New Guinea remains wild as ever, its fauna still not fully explored. In December 2005 scientists surveying the Foja Mountains in Indonesia's Papua Province, the western half of the island, came upon the Berlepsch's parotia, a bird of paradise with half a dozen springy feathers on its head. This legendary species was previously known only from a few partial specimens collected more than a century ago.

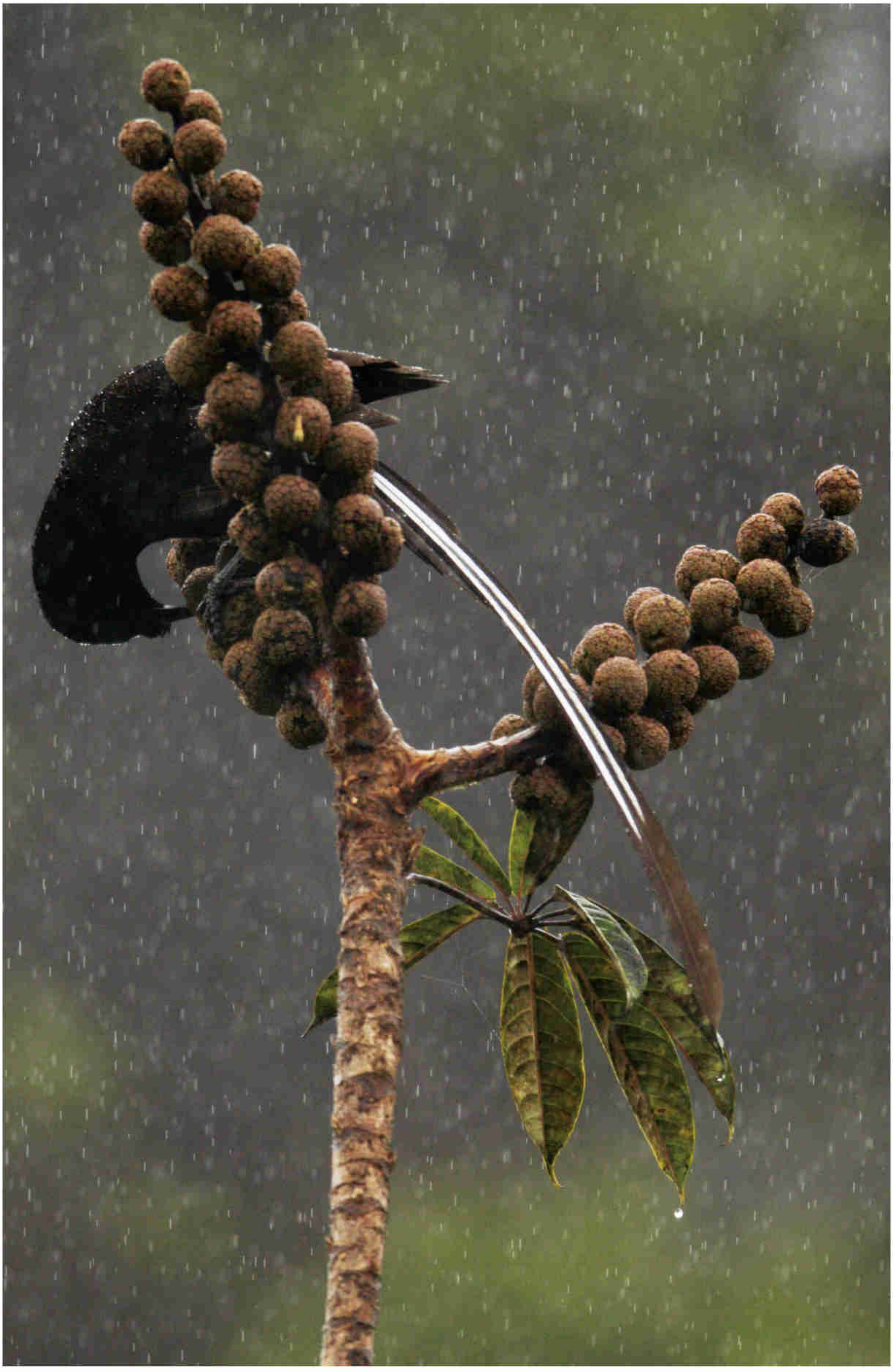
Farther east, in Papua New Guinea's Crater Mountain reserve, the forest grows dense to the mountain's summit, forming a canopy that blocks all but the thinnest rays of sun. Birdsong rings out in the gloom, a hoot here, a trill there, a melodious whistle, a harmonic tone as when a finger circles the rim of a glass. Drenched by nearly 300 inches of rain a year, this highland terrain is forever dripping. The forest floor, composed of layer on layer of organic material, is a wet sponge underfoot. And always, from somewhere below, comes the muted rush of a cold river spiriting away last night's rain.

Trails are rutted and mud-slick, swallowing boots and bruising the ankles of a first-time visitor. But the local women and children, who for a few kina will carry heavy gear and even lead you by the hand, tread lightly on bare feet. Pull out pictures of what you're looking for, and the men will lead you on long, clambering hikes, their machetes swinging to clear a path to where the birds of paradise hold court.

Even with local guides, finding the elusive birds can be daunting. Their calls, unique to each species, tantalize you. Squawks, mews, and nasal bursts reveal Carola's parotia. A ghostly aria? That's the buff-tailed sicklebill. The superb bird of paradise seems to throw its metallic voice, sending you off course. At higher elevations the King of Saxony bird crackles like radio static. And within earshot, the rat-a-tat-tat of the brown sicklebill could be machine-gun fire.

At last a glimpse of a forest dance floor reveals a weird, obsessive performance. The magnificent bird of paradise, with its baby blue cap and filigree tail, snaps into the same crisp displays again and again, puffing up its breast to show off its glossy chest plate. The parotia spends hours cleaning its court and practicing its moves, often watched by younger males eager to learn the ropes. The buff-tailed sicklebill settles on the same perch at the same time every evening, popping open its pectoral fan for any watching female—or no audience at all.

The people of New Guinea have been watching these displays for centuries. "Locals will tell you they went into the forest and copied their rituals from the birds," says Gillison. At highland sing-sings, now more tourist entertainment than true ritual, the painted and mud-daubed dancers still evoke the birds with their movements and lavish costumes. "By wearing the feathers, you get back the part of yourself that living takes





A blue bird of paradise (right) and a ribbon-tailed astrapia (left) feast on New Guinea's bounty of fruit. With food plentiful for females and chicks, males' energy has shifted over time from parental duties to lavish plumage and luring mates.

ASTRAPIA MAYERI; P. RUDOLPHI

away," Gillison says. "You capture the animal's life force. It makes you a warrior."

Headdresses, some so wide and weighty that you'd expect the wearer's neck to buckle, bear groves of feathers and whole birds skewered and upended. Black astrapia tails stand tall among plumes of the lesser bird of paradise. The iridescent breastplate of the blue bird of paradise glows among intact parrots. And a King of Saxony's white head ribbon, threaded through a woman's nose, bounces as she dances—much as when the live birds bob to attract a mate.

Surprisingly few birds die for these costumes nowadays. Ceremonial feathers are passed down from generation to generation. And although local people are still permitted to hunt birds of paradise for traditional uses, hunters usually target older males with full plumage, leaving younger males to continue breeding.

More serious threats loom. Though wholesale massacre of birds for the plume trade is long stanched, a black market still thrives. Vast palm oil plantations are swallowing up thousands of acres of bird of paradise habitat, as is large-scale industrial logging. Oil prospecting and mining are encroaching on New Guinea's wildest forests. Meanwhile, human populations continue to grow. Land ownership is fragmented among local clans, and their leaders disagree about which lands should be protected.

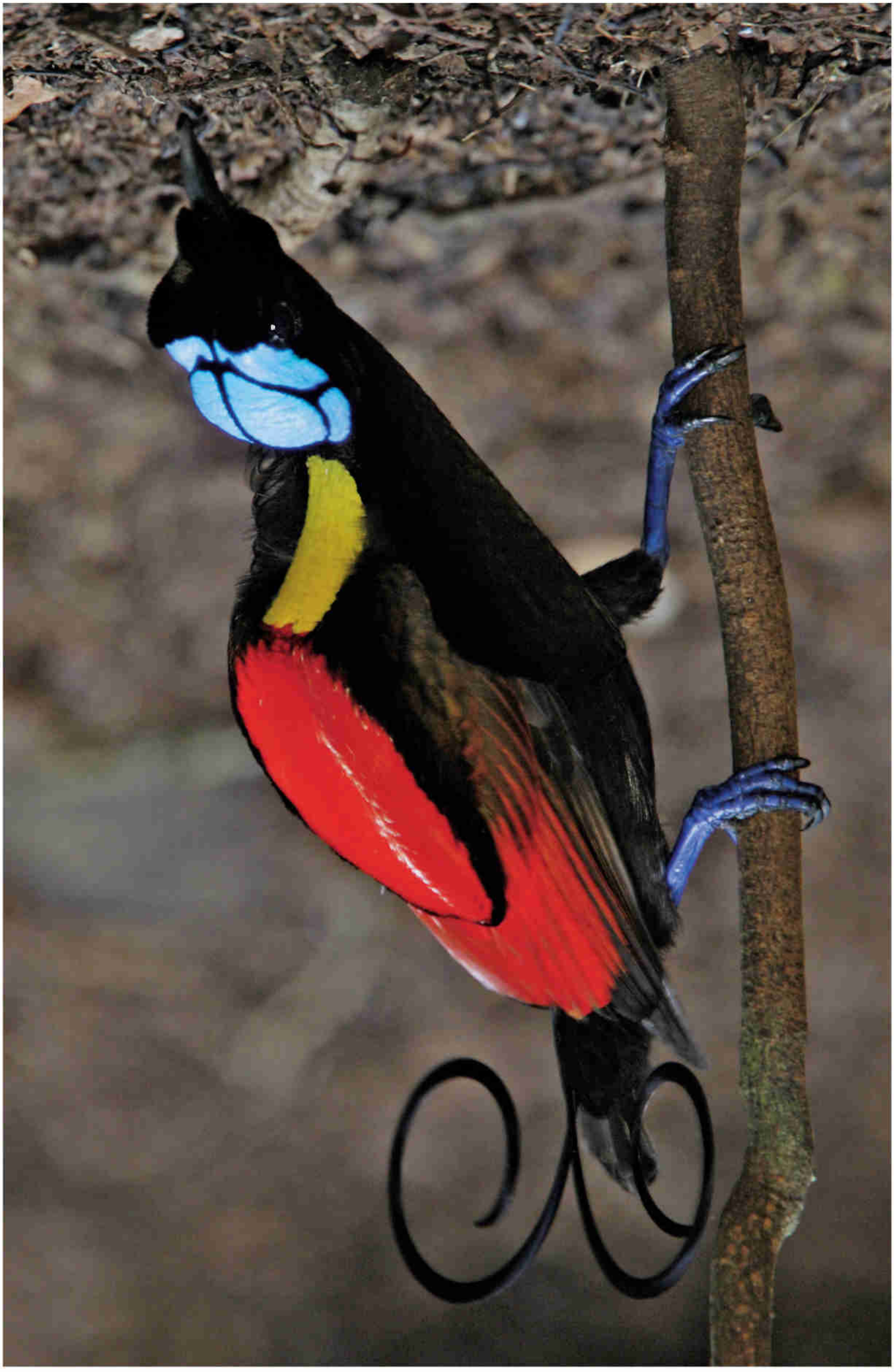
David Mitchell of Conservation International studies the Goldie's bird of paradise, a rare species with a fiery fan of plumes and a strident call that lives only on two islands off the southeastern tip of New Guinea. By enlisting local villagers to record where the birds display and what they eat, Mitchell hopes not only to glean data but also to encourage protection of the birds' habitat. The strategy seems to be working.

"I had come to cut down some trees and plant yam vines," says Ambrose Joseph, one of Mitchell's recruits. "Then I saw the birds land there, so I left the trees alone."

Mitchell is encouraged, but not sanguine. "Just because some elders become interested in forest protection won't stop others from turning the next patch into a garden," he says. "You have to keep coming back, keep telling the story and getting the next generation committed, or you lose momentum."

Meanwhile, in the dim light of the rain forest, a male bird of paradise again struts before an audience of coy females. For millions of years these exceptional birds have danced to perpetuate their kind. They'll keep dancing for as long as the forest offers them a stage.

Plumed Performers See feathered dancers—bird and human—in our online Photo Gallery, and download images for your desktop at **ngm.com/0707.**





Colorful as a court jester—and almost as comical—a male Wilson's bird of paradise woos a mate. He begins by clearing the area around his perch. Then, with whispered buzzes and clicks, he flashes his chest and shakes his handlebar mustache of a tail.

CICINNURUS RESPUBLICA







Plumes such as the King of Saxony's graceful head ribbons (above) offer ancestral strength to the people who wear them, according to local belief. At festivals of clan pride called sing-sings, costumed dancers preen, strut, and shake their feathered headdresses in rituals reminiscent of the birds' mating dances. But birds of paradise are not just figures in tribal myths. Both Papua New Guinea and neighboring Indonesia proudly display the birds on emblems, flags, and currency. Icons of New Guinea and its diverse peoples, these birds of fancy are forever embedded in cultures and minds. □

PTERIDOPHORA ALBERTI

The Truth about Tongass

Alaska's Tongass National Forest includes the greatest tracts of rain



forest outside the tropics. Subsidized logging is ripping them apart.

BEAR RESEARCHER LAVERN BEIER ON THE UNUK RIVER

Isolated rays of sunlight pierce the clouds hanging thick over Favorite Channel. Such weather is characteristic of the Tongass, where rainfall averages 146 inches yearly.



Cruise ships shoulder the shoreline in downtown Ketchikan, disgorging more than 800,000 passengers a year. Tourism has been the town's major industry since a pulp mill closed in 1997.

Holland America Line

TONGASS DOCK STORE

An Alaskan Shopping Experience

TONGASS

UPPER LEVEL

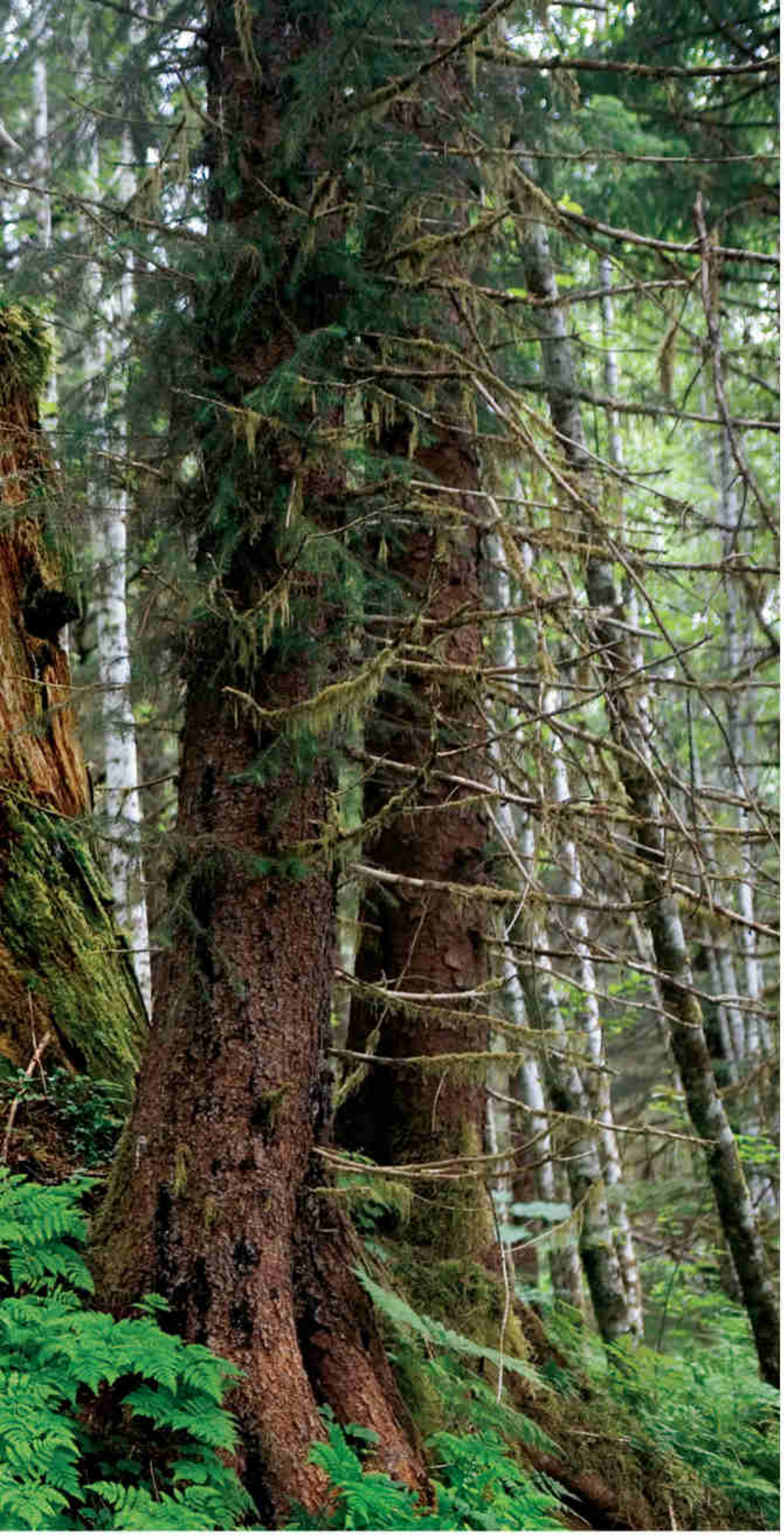
MAIN LEVEL

OUTD

ACE

By Douglas H. Chadwick
Photographs by Melissa Farlow

A strange, soft storm of white flakes is floating out of the summer sky, drifting past tall mountainside evergreens onto the nets of golden lichens hung from their boughs, onto the bushes colored by salmonberries and blueberries, onto the bear-tracked shores. This is not an unseasonal snow squall, not a flurry of wind-borne seeds. It's a fall of molted feathers from bald eagles converging on the waterways by the



Kenyon Fields, ground-truthing director of the Sitka Conservation Society, climbs down the stump of an ancient spruce he has measured. Centuries will pass before second-growth trees reach the stature of the spruce, cut in the 1960s.

hundreds, bright heads and tails gleaming like beacons all along the dark woodland slopes. A high tide of flesh surges inland from the sea: Every river, every stream, quivers with salmon thrashing upcurrent to spawn like rapids running in reverse. If any more flowing juices and beating hearts crowded in here, the place might start moving around on its own.

Big trees, big birds, big fish, big bears, immense peaks wrapped in great glaciers that break off into bays where great whales spout: This is Southeast Alaska, the state's panhandle. It separates northern British Columbia from the open Pacific with a chain of misty, fjord-footed mountains and a jigsaw puzzle of more than a thousand islands. Known as the Alexander Archipelago, the islands help explain how a region less than 500 miles long can have 18,000 miles of shoreline (almost all wild, whereas the longest stretch of undeveloped coast in the contiguous states is 30 miles), more than 10,000 estuaries, and 13,750 river miles that host oceangoing fish. About 5 percent of Southeast Alaska is owned by native tribes or the state. Another 12.5 percent makes up Glacier Bay National Park and Preserve. All the rest—16.8 million acres—is the Tongass National Forest.

Three times the size of the next largest U.S. national forest, the Tongass could hardly be further from most citizens' everyday lives. Yet logging on part of this expanse has fueled decades of acrimony, lawsuits, even intervention by Congress. The controversy—and whatever the outcome may be—has turned the remote Tongass into a central test of how Americans want to manage living resources on public lands.

National forest? National rain forest is more accurate. Make that old-growth temperate rain forest, an exceptionally rich ecosystem that holds more organic matter—more biomass—per acre than any other, including tropical jungles. And that's not counting the equally lush forests of seaweed added to Tongass shores whenever the tide goes out. Temperate rain forest flourished from Alaska to northern California and in nations from Norway to Chile. Much has fallen to the ax and saw. In the lower 48 states, 96 percent of old-growth forest of all types has been cut down. The Tongass now represents not only the greatest remaining reserve of huge trees in the U.S., but also nearly one-third of the old-growth temperate rain forest left in the world.

Rising fast from salty coves to blue ice and black crags, here's a continent edgescape to swell the soul and humble the ego. Storm waves funneling up Stephens Passage can make an aluminum skiff feel awfully small, too, as I realized the day I first set out in June. My traveling companions were Richard Carstensen, from Juneau, and Bob Christensen, who lives on a lonesome island in Icy Strait. I called them the Sen Boys for short. Both are naturalists and experts at interpreting how the lay of the land shapes plant and animal communities. They read the sea well, too, and decided to run for a sheltered inlet.

At anchor with the engine off, we could hear how hard the rain was pelting the roof. Anyone else might have lingered in the boat's little cabin. The Sen Boys hurried out to hike. Anyone else might have chosen the beach and grassy estuary. The Sen Boys headed straight for the drooping, tangled murk beneath giant Sitka spruce, western hemlock, and cedar. They're rain forest guys, and we were on a voyage of discovery through an American frontier.

A high-tech voyage: The Sen Boys' hats had pockets sewn on to hold GPS (global positioning system) devices that pinpointed their locations from satellite signals and sent the data wirelessly to PDAs (personal digital assistants) in waterproof cases on their belts. The PDA screens displayed maps that automatically adjusted to match their whereabouts as they moved. By tapping the screens they could call up map overlays showing plant communities, wildlife habitat quality, geology, and 3-D topography. Their goal was to evaluate forest resources, focusing especially on sites scheduled to be cut.

Carstensen pointed out key plants as he walked. He nibbled the tastier greens. He dropped to his belly to examine obscure mosses and rattled off their Latin names. Petal by frond, he was assembling a portrait of the habitat in his mind. Where I saw the forest floor take an abrupt rise, he saw a former shoreline uplifted since the glaciers began to retreat, relieving the land of their weight—a phenomenon called glacial rebound. It is ongoing. The Tongass stands a smidgen higher by the hour.

Meanwhile Christensen raced ahead, talking into a voice-recording digital still camera. He looked for animal trails and droppings, counted them, mapped them, fingered old bones and snagged hair, and photographed the colossal conifers. He told me that both yellow cedars and western red cedars live at least a thousand years, then led the way to spruces he judged to be about 700 years old. Their trunks were so stout the three of us joining hands couldn't have encircled one.

People joke about tree huggers, but no one laughs when old-growth woodlands are described as cathedral forests. We stand in awe amid columns that soar toward the light. The air takes on weight. It feels preternaturally close and still, yet behind the silence, is alive with faint rustlings, as in the moments before a hymn begins. I wondered whether groves of grand trees didn't in fact inspire the design of humanity's first temples and later edifices: the architecture of praise.

Toward dusk, my companions started stringing up tarps in the downpour with rapid, silent teamwork. I went looking for a place to pitch my tent that wasn't near a bear path. Impossible. When I turned back, I saw a dome tent glowing from the light of laptop computer screens. Wires and add-ons claimed half the floor. And there in the middle were the Sen Boys, each with one foot planted in bushcraft, the other in geekdom. They were hard at work compiling data from the forest. Supported by the Sitka Conservation Society, they call their effort the Tongass Ground-Truthing Project.

A century ago, President Teddy Roosevelt established the Tongass National Forest. The majority of it is as untamed today as it was then. Nearly two dozen national monuments, preserves, and designated wilderness areas within the national forest guarantee that almost seven million acres will stay that way. By contrast, half a million acres have been logged. Timber sales pending under the latest management plan will increase the total to about 650,000 acres. National forests are supposed to provide for multiple uses, from recreation to industry. So what's the problem?

The basic truth that lies behind the Tongass controversy is threefold. First, big-tree old-growth forests flourish on less than 4 percent of the land. Roughly one-third of the national forest isn't woodland at all but bare rock, glaciers, tundra, open muskeg, and slopes shorn by avalanches. Much of what remains is too

Logging's Legacy

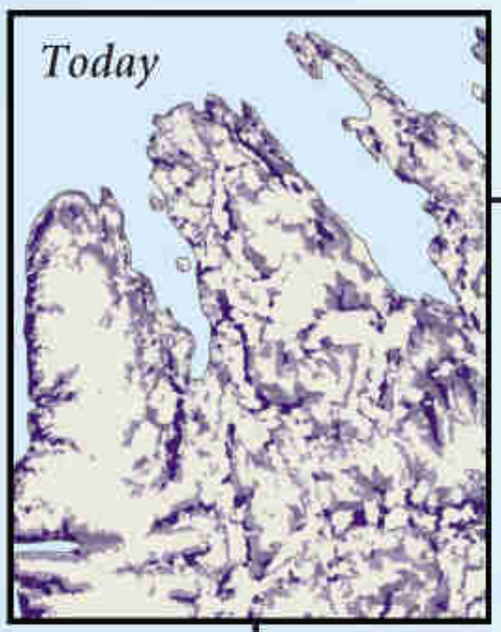
The Alaska Panhandle, which holds some of Earth's most majestic forests, is a complex patchwork of ownership—federal, state, native corporation, private—with varying protection from logging and development. Federal law protects 5.7 million acres, but those do not include some of the most valuable old-growth timber.

Tongass National Forest

- Logged area and roads *(since 1954)*
- Old-growth forest
- Other land *(low-volume forest, nonforest vegetation, and unvegetated lands)*
- Congressionally protected land *(wilderness areas, national monuments, and roadless wildlands)*
- Non-Forest Service land *(private, municipal, and other lands)*

Diminished Habitat

Stands of big trees often nourish rich ecosystems. Recent decades of logging on Kuiu Island seriously reduced deer winter habitat, shown in purple.



Deer winter habitat



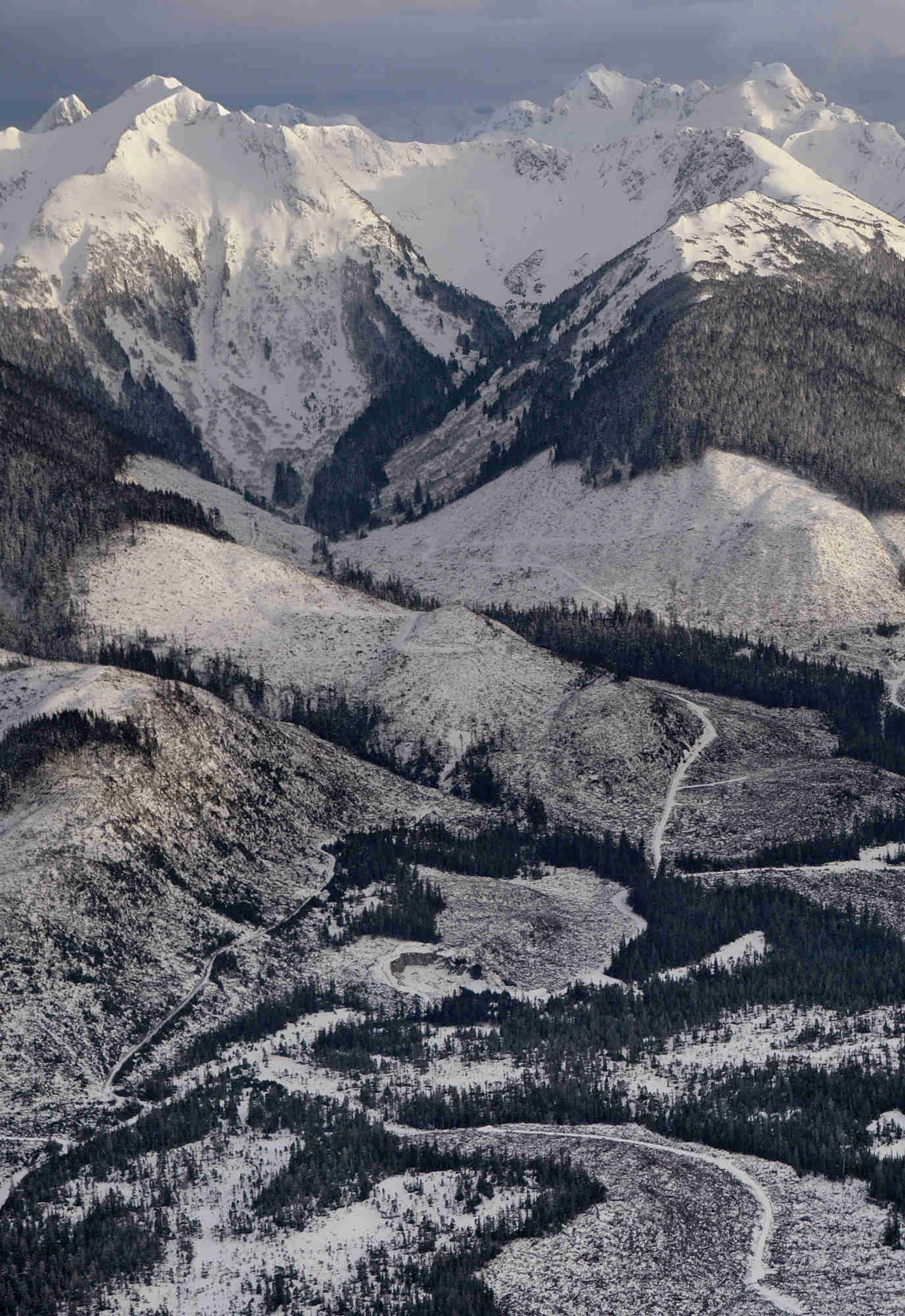
Yakutat
TONGASS NATIONAL FOREST
BRITISH COLUMBIA
ALASKA
HAINES STATE FOREST
Skagway
Haines
GLACIER BAY NATIONAL PARK AND PRESERVE
UNITED STATES
CANADA
Gustavus
Chilkat Range
Favorite Channel
Mendenhall Glacier
Juneau
Icy Strait
Hoonah
CHICHAGOF ISLAND
Stephens Passage
Tenakee Springs
Tenakee Inlet
ADMIRALTY ISLAND
TONGASS
Sitka
Kake
KUPREANOF ISLAND
Petersburg
KUIU ISLAND
NATIONAL
Wrangell
Unuk River
Coffman Cove
FOREST
Klawock
Thorne Bay
PRINCE OF WALES ISLAND
Ketchikan
Hyder
Metlakatla
ALEXANDER ARCHIPELAGO
PACIFIC OCEAN

NORTH

0 mi 50
0 km 50

SOURCES: DAVE ALBERT, THE NATURE CONSERVANCY; BOB CHRISTENSEN AND RICHARD CARSTENSEN, SITKA CONSERVATION SOCIETY; AUDUBON ALASKA; U.S. FOREST SERVICE

MARTIN GAMACHE AND LISA R. RITTER, NGM MAPS



Logging roads etch denuded slopes on Chichagof Island, owned by native corporations that have taken possession of 571,000 Tongass acres under the Alaska Native Claims Settlement Act of 1971. The majority of those acres have been cut.

Conifers hundreds of years high and wide



Shredded trunks pile up in a clear-cut on Prince of Wales Island. Sustainable forestry has not yet taken hold in Southeast Alaska. Logging here means leveling wide stretches of old-growth forest.

high and cold or too soggy to support more than stunted or average-size trees. Most of the giant conifers rise on low-elevation sites with better drained, more fertile soils, notably karst (porous limestone) formations and gravelly riversides and floodplains. Second, those forests have been the primary targets for cutting from the start. Finally, nearly a third of Southeast Alaska's big trees have already been felled. Forests come back, of course. But by the measure of a human life span, conifers hundreds of years high and wide are not really renewable resources, and extracting them is more akin to mining.

Even before the 1920s, big trees had become scarce in stretches where independent handloggers had cherry-picked shoreline forests. Alaska officials tried to lure larger timber outfits from the south. But operating so far from ready markets looked like a money-loser, and the companies stayed home. Then, shortly after World War II, the federal government stepped in with an extraordinary incentive: a guaranteed 50-year supply of national forest timber at token prices to investors willing to build pulp mills.

Giveaways of public resources don't get more blatant. However, the Tongass forests seemed vast enough to meet any demand. Neither U.S. Forest Service technicians nor anyone else had yet inventoried the terrain to see how much of it actually grew big trees. Alaska still had the quasi-colonial status of a U.S. territory (it wouldn't become a state until 1959), and ecology was still an unfamiliar word. So why not harvest a heap of wood and set the boondocks up north on the path to development, especially since commercial logging, unlike fishing, held out the promise of jobs year-round?

One objection was to the federal costs of managing the timber sales and building road

are not renewable resources, and extracting them is more akin to mining.

systems through rough-and-tumble backcountry to reach the trees—tens of millions of dollars annually, coming out of the pockets of U.S. taxpayers and padding company profits. But this subsidy was framed by a concern all too familiar today: national security. With Japan's wartime invasion of the Aleutian Islands fresh in mind, Congress wanted more Americans in Alaska. Moreover, the Cold War had begun, and strategists feared that Japan, struggling to rebuild, might turn to the Soviet Union for timber from Siberia.

An American corporation began operating the first huge pulp mill in 1954 near the fishing town of Ketchikan. A second was built soon after in Sitka by a Japanese consortium. Alaska's biggest industrial facilities in the era before North Slope oil, each hired some 500 people at relatively high wages. Many more were employed as sawyers, bulldozer operators, and drivers to keep an annual volume of 200 to 600 million board feet of timber (about 20,000 to 60,000 logging truckloads) flowing to the mills. There, the straight trunks of big hemlocks and the dense-grained, incredibly strong wood of Sitka spruce, many of the spruce trees born two or three centuries before Europeans knew the New World existed, were shredded and soaked in chemical brews—pulped. The pulp was shipped off to make rayon, cellophane, newspaper, and absorbent filling for disposable diapers.

Those who oppose wildland conservation sometimes say, "You can't eat the scenery." Ironically, we all ended up making meals out of old-growth Tongass woodlands: A separate milling process yielded a hemlock-and-spruce-fiber mash that qualified as edible pulp, a common additive in ice cream, jellies, and other processed foods. As the patterns of road webs and clear-cuts spread, voices of protest began to be raised.

Perhaps the greatest worry was not over the majestic trees themselves but over wildlife in the wake of logging. Commercial fishing was still Southeast Alaska's most important industry. Sportfishing and hunting also brought in a good deal of revenue, while both native and white residents depended upon fish and game for subsistence. Grizzlies and black bears favor old-growth stands much of the year. After the bears go to sleep, the canopy of branches keeps heavy snowfalls from burying winter forage vital to black-tailed deer, a type of mule deer adapted to coastal rain forest.

Blacktails in turn are the mainstay of the Alexander Archipelago wolf, a smaller, darker subspecies of the gray wolf. During the past decade, researchers have learned that some packs spend a surprising amount of time catching salmon, too. Undisturbed watersheds favor strong spawning runs: The towering shade keeps streams cool, fallen trunks slow down currents and create pools, woodland nutrients fertilize the food chain that young fish rely upon. Closing the circle, generations of returning salmon help grow those very trees over time as fish-eating wolves, bears, eagles, gulls, and other animals spread around carcasses and excrement, all loaded with nitrogen and phosphorus from the ocean realm. It's like sprinkling Mrs. Nature's Supergro Mix onto a garden bed.

Forest economists have different ways of describing such habitats. "Overmature" is one. "Decadent," and "stagnating" are popular. The favorite is still "falling down and going to waste." All imply that where we don't harvest a forest to stimulate a new round of growth, the system lingers past its prime and decays. Well, they have a point, but only from the standpoint of maximum timber production. In terms of the maximum production of life, they are not seeing the forest for the trees.

Ground littered with broken branches and the trunks of titans that crashed to earth, creating openings above; all those mulches and mushrooms and composting tree tissues and burrowing, wriggling, scavenging little animal forms—these are signs of vitality in a woodland. The

The controversy has turned the Tongass into



A tranquilized brown bear is radio-collared by state biologists. Research in Tongass shows that bears are sensitive to logging. Females make less use of streams in heavily exploited watersheds.

older the forest, the more complex its structure and ecological functions, and the wider the array of niches for flora and fauna. From lichens and liverworts to millipedes and mink, the richest assortment of life-forms in the rain forest ecosystem is housed within old-growth stands. They are the countryside's hot spots of biodiversity. Antiquity is their prime.

One cure for age discrimination against elderly habitat is to hike through what replaces it after logging. Rain forests erupt with vegetation; it's their specialty. In clear-cuts, the result is a barricade of flexible shrub stems, spruce sapling needles, and sharper thorns. When surveying clear-cuts for signs of wildlife, the Sen Boys jokingly rated each bushwhack on a misery index from one to ten.

By four, you're in an obstacle course where forward progress requires using your hands as much as your feet. Feet rarely touch the ground after six. They are either searching for balance atop springy branches or caught in—well, difficult to say, because you can't see your feet through the leaves. Jungle-gymming up a mountainside where the branches all point downhill counts as an eight. One step forward, two stumbles back. When you grab for something to stop your slide, it's too often *Oplopanax horridum*—devil's club, the thorniest plant around.

"This has got to be a nine," I said while we fought our way up a thick, slick, spiked slope in a drizzle.

"Nope," Christensen called over. "Nine is way worse."

"What's a nine, then?"

"A nine is when it's raining hard and the bugs are really bad."

Deer, moose, and bears don't find the going easy in logged-over acreage either, but they have a bonanza of herbs and berries to choose from

a test of how Americans want to manage living resources on public lands.

during the warm months. From late fall through spring, though, the food in clear-cuts is mostly out of reach beneath deep snow. Within 20 to 30 years, young trees will have taken over in such numbers that their branches interlace to form what foresters call a closed canopy stand. Little light gets through to lower levels. For a creature in search of a meal, the gloomy floor of a second-growth rain forest might as well be a desert for 50 to 100 years.

In 1968, the Forest Service awarded a contract to U.S. Plywood-Champion Papers, Inc., to cut trees for pulp on Admiralty Island. Long known to Tlingit tribes as Kootznoowoo, Fortress of the Bears, the million-acre island supports one grizzly per square mile. Public pressure mounted, and eventually, in 1978, the whole of Admiralty was set aside as a national monument.

Meanwhile, the 1971 Alaska Native Claims Settlement Act had given the various native corporations across the state ownership of lands they selected from federal holdings. The total in Southeast Alaska came to more than 500,000 acres. Advised by timber economists, the native regional corporations and villages picked out mainly lands with productive big-tree forests. Then they began to level them and sell the raw logs to Asian markets, almost matching the pulp mills' rate of timber consumption.

Next came ANILCA, the Alaska National Interest Lands Conservation Act of 1980, which established 104.3 million acres of parks, wildernesses, and other reserves throughout the largest state. In a trade-off engineered by Alaska's congressional delegation, the same bill mandated that the mills in the Tongass be supplied with a minimum of 450 million board feet of timber and a 40-million-dollar annual subsidy—primarily to build roads to access timber.

People on both sides of the Tongass dispute get mad at the Forest Service. Maybe it is more to be pitied—as the recipient of conflicting marching orders. The new law essentially forced the agency to promote heavy logging even as other laws held it responsible for protecting wildlife and watersheds. Citizens outside the state were increasingly alarmed by the pace of rain forest destruction and annoyed that they were funding it.

While the Tongass was losing habitat and also far more money on the timber program than any other national forest, Southeast Alaska tourism was booming, beginning to compete with traditional industries for the lead role in the economy. The major draws were the region's natural beauty and spectacular wildlife. In 1990, Congress responded with the Tongass Timber Reform Act, which repealed the mandated timber supply and subsidy. Three years later, the Sitka mill closed. The Ketchikan mill closed its doors in 1997.

On Prince of Wales Island, the most extensively roaded and chopped-over piece of the Tongass, a former logger and millwright, Bob Widmyer, looked around at the quiet village of Coffman Cove. He and his wife had been planning to retire after five more years at the Ketchikan mill. Instead, he said, "They decided they had to save all the trees and shut down the mill, and everybody here and in Ketchikan started to starve." The Widmyers ended up at a culinary arts school in Arizona. They were back in Alaska now, and he operated a commercial fishing boat. "I'm kinda bitter," he told me. "This is a damn rain forest. It was put here to log."

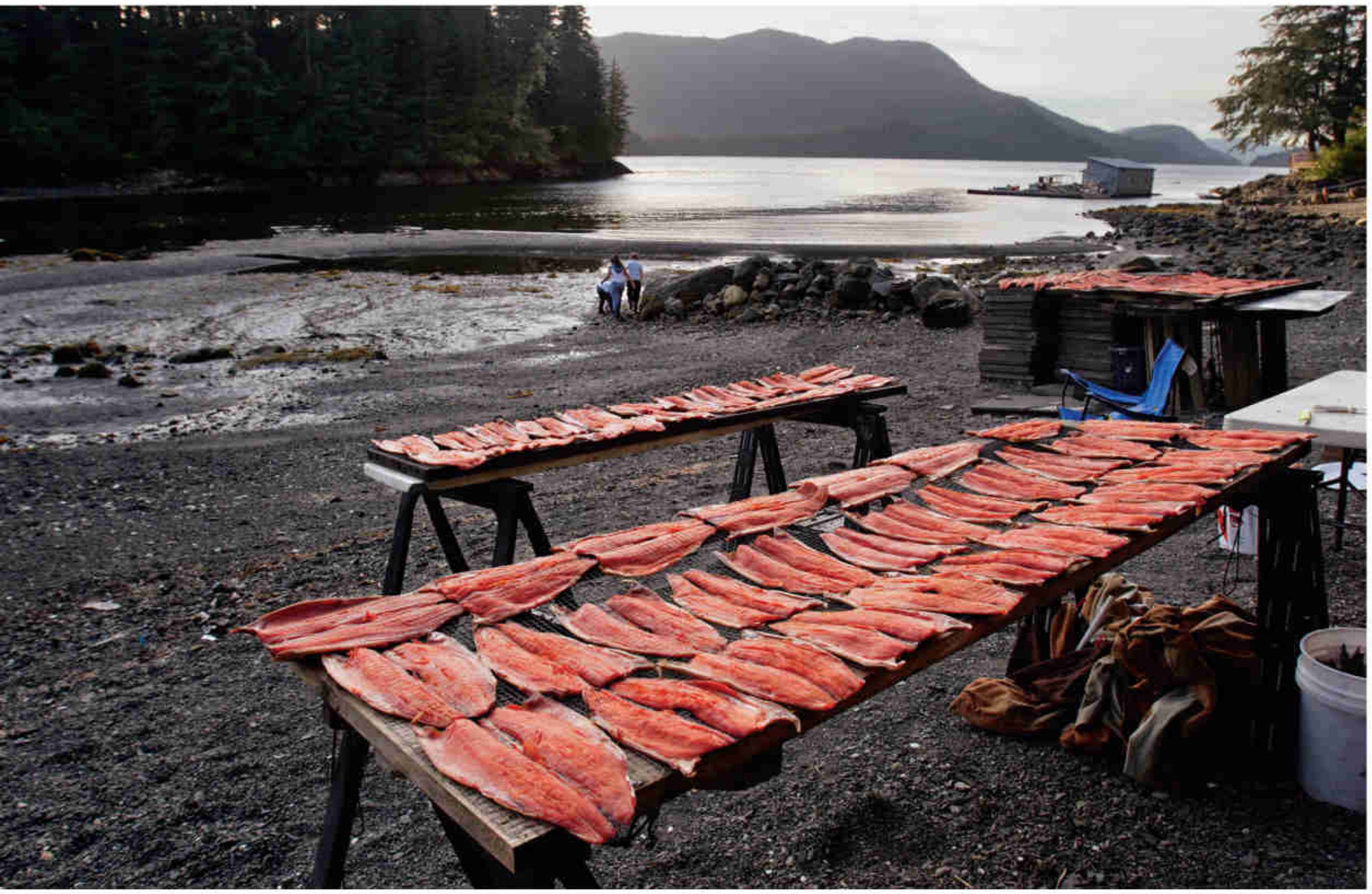
Some blamed environmental activists and the Timber Reform Act for throwing people out of work, but others argued that the mill closures had more to do with a sharp recession in Japan, a slumping world market for pulp, and Alaska's disadvantage in competing against countries with faster growing trees and less expensive pulp production methods. Ketchikan's mill was also facing serious air- and water-pollution fines.

The saga rumbled on. In 1999, undeveloped national forest lands across the U.S. were

Muscling his end of the misery whipsaw at a logging contest, Cody Thomas goes for the prize. About 500 people still work in the South-east Alaska timber industry, which has lost 1,400 jobs since 1996.


ALASKA
LOGG

The government could pay each logger and



Salmon await the smokehouse at Dog Point Fish Camp near Sitka. Here Tlingit youngsters forgo modern temptations—video games, junk food—to learn traditional ways from elders.

declared off-limits to commercial logging. In 2001, outgoing President Bill Clinton included nearly ten million Tongass acres. The exemption became known as the Roadless Rule. Incoming President George W. Bush rescinded it, giving authority over such decisions to individual states. Lawsuits followed. A federal judge issued a decision in 2006 stating that the Bush Administration was not justified in rolling back those protections for wildland resources.

Lawyers continue to pile on. But in 2003, the undersecretary of agriculture in charge of the Forest Service, Mark Rey, a former timber lobbyist, declared one forest's roadless areas open to timber management no matter how the issue was resolved nationally. That one was the Tongass. It seems to have become a symbol in a much larger contest of beliefs about what frontiers are for and what the truest measure of a nation's progress should be.

When the Sen Boys took off ground-truthing one rare, hot, blue-sky morning, I devoted myself to sea-truthing in a kayak instead. Kelp beds and their galaxies of star-shaped, whorled, gilled, and tentacled inhabitants are part of the Tongass experience too. Later, I paddled back to the island where our tents were and lay beneath a spruce 11 feet across and 225 feet tall. Mosses and fallen bark and twigs were piled so deep at its base that the forest floor felt like a mattress. According to some experts, more than 90 percent of the giants among giants—trees exceeding ten feet in diameter, "the big pumpkins" as sawyers say—are gone. It was a privilege to just hang out with one.

With only three modest-size mills and ten small ones scattered around the region today, the Tongass timber industry provides about 200 jobs—less than one percent of total employment in Southeast Alaska. The gargantuan cruise

mill worker $146,250 a year to stay home and let the rain forest be.

ships plying the waters hire nearly a thousand workers—on each vessel. In Ketchikan alone (city population 8,000), more than 800,000 visitors walk off cruise ship decks and into the stores every year, generating upwards of 120 million dollars in tourism revenue.

The Tongass National Forest itself has a staff of 600 to 700. In an average year, the agency spends some 30 million dollars overseeing timber programs. Many of the logging sales it puts up for bid have no takers. Others stay in limbo because of lawsuits filed by conservationists. For the approximately 50 million board feet the Forest Service does manage to sell annually, it receives about $750,000. The deficit therefore comes to $29,250,000. Dividing that by 200 Tongass timber jobs, the government could pay each logger and mill worker $146,250 a year to stay home and let the rain forest be.

Not going to happen? Then what about shifting the focus to repairing streams and enhancing fisheries in some of the worst-hit sites? Or thinning closed-canopy forests to hasten tree growth where the land has already been altered? The Forest Service has been experimenting with these options and more for at least 25 years.

In the pulp mills' heyday, Larry Trumble worked as a scaler, gauging how many board feet logs contained. When I tracked him down near the town of Klawock on Prince of Wales Island, he was working a one-man mill, carefully sawing thin plates from blocks of a six-foot-diameter spruce. The tight, evenly spaced grain of old trees that grow slowly in shady settings is valued as veneer in Asia. It also makes ideal soundboards for such stringed instruments as guitars and pianos. Participating in a new Forest Service program called micro sales, Trumble is allowed to pick out a few standing dead or fallen trees and haul them from the forest to be transformed into music wood. "This is the same wood that the mills ground up for chips. Cutting it into regular two-by-fours like mills do today isn't value-added either. You should get a fortune from 50,000 board feet of this stuff."

Close to the island's town of Thorne Bay, Rick Cabe operates a mill that processes three-quarters of a million board feet of timber a year. "We can't compete with mills in Canada that cut a million board feet a day for export," he told me. "We wanted to get into a high value-added operation. The lumber you see around the yard isn't that old, maybe 150 years, but it's beautiful wood."

Cabe and a crew of four selectively cut trees in timber sale units designed by the Forest Service specifically for small mills like this. They turn out long, straight-grained boards and also cut six-by-sixes rounded on one side to make log cabin kits tailored for Southeast Alaska's wet climate. The trick is to dry the wood well to prevent later settling and warping. Cabe does this in a kiln he operates for 50 cents a day. "It makes the whole operation pay off. This is a success story. Why don't more timber guys do it? It takes capital to start up." Another reason is that many small operators were driven out of business during the time the pulp mills reigned.

"Under the latest Tongass guidelines, clear-cuts are supposed to be restricted in size," Carstensen said. "But as soon as the trees growing back average five feet tall, it's legal to clear-cut the area next door, and so on. It's a prescription for what we call creeping mega-cuts. They lead to huge tracts of closed-canopy second-growth."

Nobody's cheating here: maybe fudging some, but mostly trying to keep to the management plan. Forest Service officials I spoke with were open about seeking ways to improve the plan. The agency has repeatedly put out calls for suggestions from the public. Representatives expected to hear the usual requests to close a particular road, save a special mountainside, or protect the rare lily-nosed wangdoodle.

But the computer age has changed the game. Given the latest software and high-speed Internet access to websites with technical reports

High winds scour peaks on the Chilkat Range. Of the Tongass Forest's 16.8 million acres, the majority is glacier, rock, or scrub. Industry and conservationists spar over some 600,000 acres of surviving big-tree forestland.





and satellite maps, ordinary citizens can have almost as much data at their fingertips as agency specialists. Information equality: It is a wonderfully democratic trend, and it is shifting the emphasis in resource debates from emotions toward facts. I doubt anyone envisioned public input as comprehensive as the Sen Boys' Ground-Truthing Project.

The Alaska office of the National Audubon Society joined with the Nature Conservancy to take the Forest Service request further. Audubon Alaska's senior scientist, John Schoen, explained the latest analysis of Tongass landscapes.

First, Schoen and the Conservancy's Dave Albert subdivided the region into biogeographic provinces and the watershed units (used by Forest Service planners) within them. They overlaid physical factors such as soil type, vegetation, and elevation with habitat quality maps for grizzly and black bears, wintering black-tailed deer, nesting marbled murrelets, five species of Pacific salmon, and steelhead trout. Then they added the distribution of big trees and estuaries.

Each of these factors is an indicator of productive habitat. The more they overlap, the richer that area is ecologically. To rank the multitude of areas, Schoen and Albert turned to a potent computer program called Marxan. At its digital



Anna and John Bohach staged their wedding in "God's great cathedral," as Anna calls Tongass's Mendenhall Glacier. Tongass was set aside for diverse uses—including commerce—but care is necessary so that increased human pressure does not diminish its unearthly glory.

heart is an algorithm designed to solve a problem, arriving at the optimal solution by comparing tens of millions of alternative solutions. Gazillions of calculations later, the men held in their hands a map of the Tongass Forest's life-support systems, watershed by watershed, highlighting what Schoen termed "the best of the best."

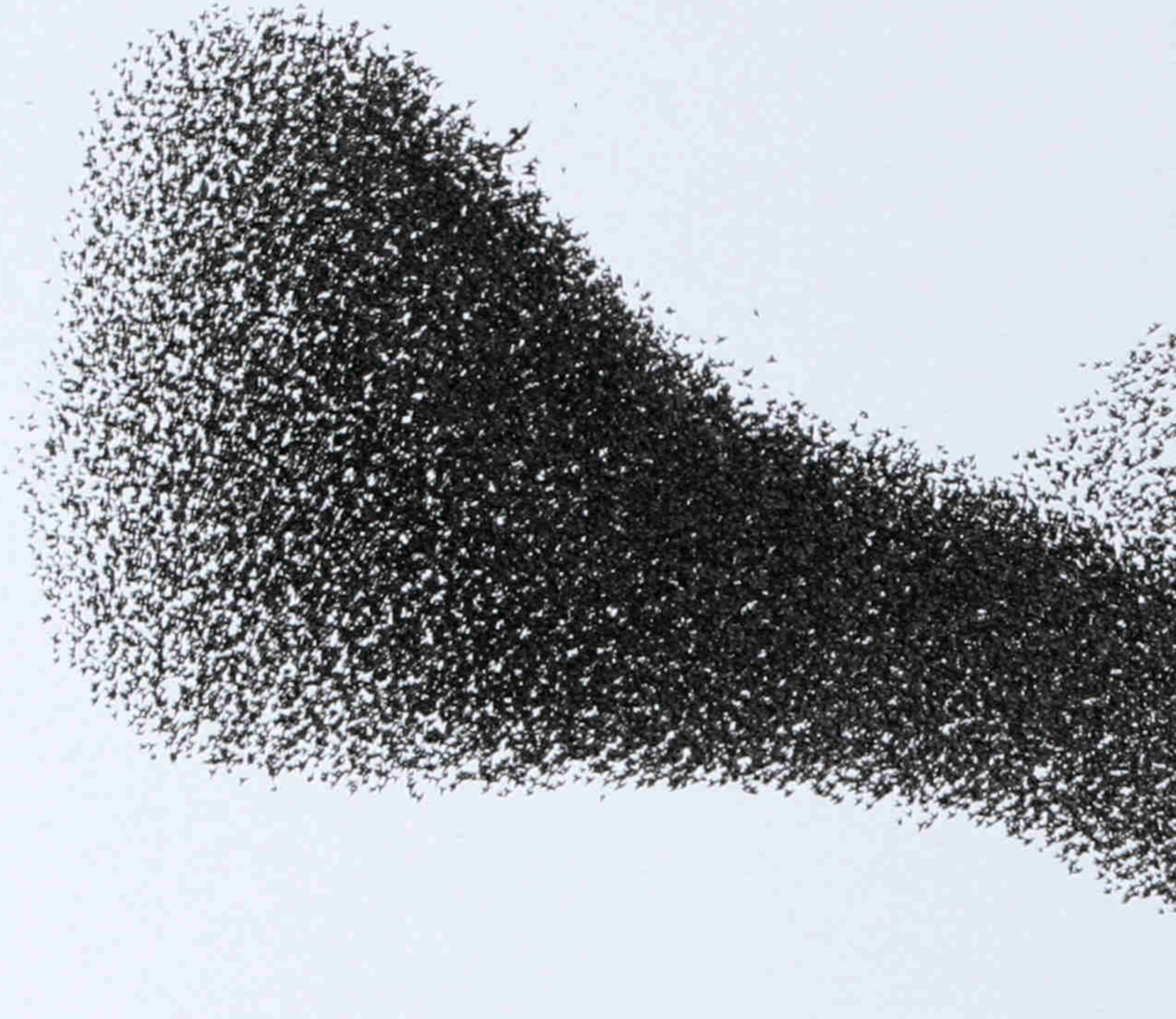
From Tenakee Inlet on the east side of Chichagof Island, Schoen and I explored a series of drainages by skiff and rubber boots to field-check the results. This was where Marxan met the mud. We slogged up estuaries rank with grizzly droppings and salmon remains beneath scudding gulls, eagles, and mists. We'd already passed one grizzly swimming half a mile from land. There were seven more among the shoreline grasses. Once deep in the woods, Schoen showed me trees the bears had marked with claws and teeth, and yellow cedars they had stripped bark from to get at the tasty cambium layer underneath.

John Schoen knows his bears. In his previous job as an Alaska Department of Fish and Game biologist, he radio-collared grizzlies and learned how closely their seasonal activities were linked to productive old-growth. Earlier, he had ruffled a lot of Forest Service uniforms with his studies of black-tailed deer habitat use. The prevailing view was that logging benefited deer by opening up those old falling-down-and-going-to-waste forests. Schoen and colleagues Charlie Wallmo and Matt Kirchhoff showed deer using old-growth five times more often than cut-over stands, a Tongass truth the timber industry was not tickled to hear.

Audubon Alaska proposes that the Forest Service set aside as off-limits the top 50 percent of undeveloped watersheds still open to logging to keep them as intact as possible. "National forest management has been commodity-driven," Schoen says. "The overriding goal was to 'get out the cut.' We're past that. Everybody is trying to figure out how to do a better job of managing all the values the Tongass has to offer. This is a world-class ecosystem. Its resources deserve world-class efforts to sustain them."

With so much of the American frontier in the rearview mirror, we begin to see more clearly that no forest has ever been just a repository of trees. Each is at once a vibrant structure, a community, the live scaffolding within which creation continues to unfold. That is the ultimate natural resource growing out there between Alaska's snow-bright summits and the sea. □

Inside Tongass Hear photographer Melissa Farlow's take on the issues behind the images of Alaska's Tongass National Forest at **ngm.com/0707**.



swarm theory

Ants, bees, and birds teach us how to cope with a complex world.



A flock of starlings takes evasive action as a peregrine falcon attacks (above, at upper left, and following pages). The ability of animal groups to shift shape as one, even when they have no leader, reflects the genius of collective behavior—something scientists are now tapping to solve human problems.

MANUEL PRESTI (PAGES 126-9)



By Peter Miller NATIONAL GEOGRAPHIC STAFF

I used to think ants knew what they were doing. The ones marching across my kitchen counter looked so confident, I just figured they had a plan, knew where they were going and what needed to be done. How else could ants organize highways, build elaborate nests, stage epic raids, and do all the other things ants do?

Turns out I was wrong. Ants aren't clever little engineers, architects, or warriors after all —at least not as individuals. When it comes to deciding what to do next, most ants don't have a clue. "If you watch an ant try to accomplish something, you'll be impressed by how inept it is," says Deborah M. Gordon, a biologist at Stanford University.

How do we explain, then, the success of Earth's 12,000 or so known ant species? They must have learned something in 140 million years.

"Ants aren't smart," Gordon says. "Ant colonies are." A colony can solve problems unthinkable for individual ants, such as finding the shortest path to the best food source, allocating workers to different tasks, or defending a territory from neighbors. As individuals, ants might be tiny dummies, but as colonies they respond quickly and effectively to their environment. They do it with something called swarm intelligence.

Where this intelligence comes from raises a fundamental question in nature: How do the simple actions of individuals add up to the complex behavior of a group? How do hundreds of honeybees make a critical decision about their hive if many of them disagree? What enables a school of herring to coordinate its movements so precisely it can change direction in a flash, like a single, silvery organism? The collective abilities of such animals—none of which grasps the big picture, but each of which contributes to the group's success—seem miraculous even to the biologists who know them best. Yet during the past few decades, researchers have come up with intriguing insights.

One key to an ant colony, for example, is that no one's in charge. No generals command ant warriors. No managers boss ant workers. The queen plays no role except to lay eggs. Even with half a million ants, a colony functions just fine with no management at all—at least none that we would recognize. It relies instead upon countless interactions between individual ants, each of which is following simple rules of thumb. Scientists describe such a system as self-organizing.

Consider the problem of job allocation. In the Arizona desert where Deborah Gordon studies red harvester ants *(Pogonomyrmex barbatus)*, a colony calculates each morning how many workers to send out foraging for food. The number can change, depending on conditions. Have foragers recently discovered a bonanza of tasty seeds? More ants may be needed to haul the bounty home. Was the nest damaged by a storm last night? Additional maintenance workers may be held back to make repairs. An ant might be a nest worker one day, a trash collector the next. But how does a colony make such adjustments if no one's in charge? Gordon has a theory.

Ants communicate by touch and smell. When one ant bumps into another, it sniffs with its antennae to find out if the other belongs to the same nest and where it has been working. (Ants that work outside the nest smell different from those that stay inside.) Before they leave the nest each day, foragers normally wait for early morning patrollers to return. As patrollers enter the nest, they touch antennae briefly with foragers.

"When a forager has contact with a patroller, it's a stimulus for the forager to go out," Gordon says. "But the forager needs several contacts no more than ten seconds apart before it will go out."

To see how this works, Gordon and her collaborator Michael Greene of the University of Colorado at Denver captured patroller ants as they left a nest one morning. After waiting half an hour, they simulated the ants' return by dropping glass beads into the nest entrance at





Tanker trucks with cargoes of liquid nitrogen, oxygen, and argon in Pasadena, Texas, are assigned delivery routes by dispatchers using a computer program inspired by the foraging behavior of ants. Just as army ants work together to find food to haul back to the group (top), so "virtual ants" in the truck-routing program cooperate to pick the best route.

regular intervals—some coated with patroller scent, some with maintenance worker scent, some with no scent. Only the beads coated with patroller scent stimulated foragers to leave the nest. Their conclusion: Foragers use the rate of their encounters with patrollers to tell if it's safe to go out. (If you bump into patrollers at the right rate, it's time to go foraging. If not, better wait. It might be too windy, or there might be a hungry lizard waiting out there.) Once the ants start foraging and bringing back food, other ants join the effort, depending on the rate at which they encounter returning foragers.

"A forager won't come back until it finds something," Gordon says. "The less food there is, the longer it takes the forager to find it and

CHRISTIAN ZIEGLER, MINDEN PICTURES (TOP); PETER ESSICK





Even though swarming honeybees frequently differ about where to establish a new nest, the group usually chooses the best site. Bees reach this decision by gathering information, conducting independent evaluations, and holding a kind of vote—the same practices used by traders in Chicago that drive the price of soybean futures.

get back. The more food there is, the faster it comes back. So nobody's deciding whether it's a good day to forage. The collective is, but no particular ant is."

That's how swarm intelligence works: simple creatures following simple rules, each one acting on local information. No ant sees the big picture. No ant tells any other ant what to do. Some ant species may go about this with more sophistication than others. (*Temnothorax albipennis,* for example, can rate the quality of a potential nest site using multiple criteria.) But the bottom line, says Iain Couzin, a biologist at Oxford and Princeton Universities, is that no leadership is required. "Even complex behavior may be coordinated by relatively simple interactions," he says.

PETER ESSICK (BOTH)

Even with half a million ants, a colony functions just fine with no management at all.

Inspired by the elegance of this idea, Marco Dorigo, a computer scientist at the Université Libre in Brussels, used his knowledge of ant behavior in 1991 to create mathematical procedures for solving particularly complex human problems, such as routing trucks, scheduling airlines, or guiding military robots.

In Houston, for example, a company named American Air Liquide has been using an ant-based strategy to manage a complex business problem. The company produces industrial and medical gases, mostly nitrogen, oxygen, and hydrogen, at about a hundred locations in the United States and delivers them to 6,000 sites, using pipelines, railcars, and 400 trucks. Deregulated power markets in some regions (the price of electricity changes every 15 minutes in parts of Texas) add yet another layer of complexity.

"Right now in Houston, the price is $44 a megawatt for an industrial customer," says Charles N. Harper, who oversees the supply system at Air Liquide. "Last night the price went up to $64, and Monday when the cold front came through, it went up to $210." The company needed a way to pull it all together.

Working with the Bios Group (now NuTech Solutions), a firm that specialized in artificial intelligence, Air Liquide developed a computer model based on algorithms inspired by the foraging behavior of Argentine ants *(Linepithema humile)*, a species that deposits chemical substances called pheromones.

"When these ants bring food back to the nest, they lay a pheromone trail that tells other ants to go get more food," Harper explains. "The pheromone trail gets reinforced every time an ant goes out and comes back, kind of like when you wear a trail in the forest to collect wood. So we developed a program that sends out billions of software ants to find out where the pheromone trails are strongest for our truck routes."

Ants had evolved an efficient method to find the best routes in their neighborhoods. Why not follow their example? So Air Liquide combined the ant approach with other artificial intelligence techniques to consider every permutation of plant scheduling, weather, and truck routing—millions of possible decisions and outcomes a day. Every night, forecasts of customer demand and manufacturing costs are fed into the model.

"It takes four hours to run, even with the biggest computers we have," Harper says. "But at six o'clock every morning we get a solution that says how we're going to manage our day."

For truck drivers, the new system took some getting used to. Instead of delivering gas from the plant closest to a customer, as they used to do, drivers were now asked to pick up shipments from whichever plant was making gas at the lowest delivered price, even if it was farther away.

"You want me to drive a hundred miles? To the drivers, it wasn't intuitive," Harper says. But for the company, the savings have been impressive. "It's huge. It's actually huge."

Other companies also have profited by imitating ants. In Italy and Switzerland, fleets of trucks carrying milk and dairy products, heating oil, and groceries all use ant-foraging rules to find the best routes for deliveries. In England and France, telephone companies have made calls go through faster on their networks by programming messages to deposit virtual pheromones at switching stations, just as ants leave signals for other ants to show them the best trails.

In the U.S., Southwest Airlines has tested an ant-based model to improve service at Sky Harbor International Airport in Phoenix. With about 200 aircraft a day taking off and landing on two runways and using gates at three concourses, the company wanted to make sure that each plane got in and out as quickly as possible, even if it arrived early or late.

"People don't like being only 500 yards away from a gate and having to sit out there until another aircraft leaves," says Doug Lawson of Southwest. So Lawson created a computer model of the airport, giving each aircraft the ability to remember how long it took to get into and away from each gate. Then he set the model in motion to simulate a day's activity.

"The planes are like *(Continued on page 138)*



Because each individual is paying close attention to its neighbors, news travels fast through a school of bigeye jack near Cocos Island in the Pacific. The fish follow simple rules that keep the group alert: stick together, avoid collisions, and swim in the same direction.

DAVID HALL

Wildebeests crossing the Mara River in Kenya may be able to follow a migration route even if only a few of them know the way, say researchers using a computer model of herd behavior. Never mind that the informed animals aren't trying to lead. The rest follow anyway.

WINFRIED WISNIEWSKI, FOTO NATURA



Almost any group that follows the bees' rules will make itself smarter.

ants searching for the best gate," he says. But rather than leaving virtual pheromones along the way, each aircraft remembers the faster gates and forgets the slower ones. After many simulations, using real data to vary arrival and departure times, each plane learned how to avoid an intolerable wait on the tarmac. Southwest was so pleased with the outcome, it may use a similar model to study the ticket counter area.

WHEN IT COMES to swarm intelligence, ants aren't the only insects with something useful to teach us. On a small, breezy island off the southern coast of Maine, Thomas Seeley, a biologist at Cornell University, has been looking into the uncanny ability of honeybees to make good decisions. With as many as 50,000 workers in a single hive, honeybees have evolved ways to work through individual differences of opinion to do what's best for the colony. If only people could be as effective in boardrooms, church committees, and town meetings, Seeley says, we could avoid problems making decisions in our own lives.

During the past decade, Seeley, Kirk Visscher of the University of California, Riverside, and others have been studying colonies of honeybees *(Apis mellifera)* to see how they choose a new home. In late spring, when a hive gets too crowded, a colony normally splits, and the queen, some drones, and about half the workers fly a short distance to cluster on a tree branch. There the bees bivouac while a small percentage of them go searching for new real estate. Ideally, the site will be a cavity in a tree, well off the ground, with a small entrance hole facing south, and lots of room inside for brood and honey. Once a colony selects a site, it usually won't move again, so it has to make the right choice.

To find out how, Seeley's team applied paint dots and tiny plastic tags to identify all 4,000 bees in each of several small swarms that they ferried to Appledore Island, home of the Shoals Marine Laboratory. There, in a series of experiments, they released each swarm to locate nest boxes they'd placed on one side of the half-mile-long island, which has plenty of shrubs but almost no trees or other places for nests.

In one test they put out five nest boxes, four that weren't quite big enough and one that was just about perfect. Scout bees soon appeared at all five. When they returned to the swarm, each performed a waggle dance urging other scouts to go have a look. (These dances include a code giving directions to a box's location.) The strength of each dance reflected the scout's enthusiasm for the site. After a while, dozens of scouts were dancing their little feet off, some for one site, some for another, and a small cloud of bees was buzzing around each box.

The decisive moment didn't take place in the main cluster of bees, but out at the boxes, where scouts were building up. As soon as the number of scouts visible near the entrance to a box reached about 15—a threshold confirmed by other experiments—the bees at that box sensed that a quorum had been reached, and they returned to the swarm with the news.

"It was a race," Seeley says. "Which site was going to build up 15 bees first?"

Scouts from the chosen box then spread through the swarm, signaling that it was time to move. Once all the bees had warmed up, they lifted off for their new home, which, to no one's surprise, turned out to be the best of the five boxes.

The bees' rules for decision-making—seek a diversity of options, encourage a free competition among ideas, and use an effective mechanism to narrow choices—so impressed Seeley that he now uses them at Cornell as chairman of his department.

"I've applied what I've learned from the bees to run faculty meetings," he says. To avoid going into a meeting with his mind made up, hearing only what he wants to hear, and pressuring people to conform, Seeley asks his group to identify all the possibilities, kick their ideas around for a while, then vote by secret ballot. "It's exactly what the swarm bees do, which gives a group time to let the best ideas emerge and win. People are usually quite amenable to that."

In fact, almost any group that follows the bees' rules will make itself smarter, says James



Biologists in an Oxford lab show that when otherwise harmless juvenile locusts get too crowded, they will suddenly align themselves and march in the same direction, triggering a potentially devastating swarm.

PETER ESSICK

Surowiecki, author of *The Wisdom of Crowds.* "The analogy is really quite powerful. The bees are predicting which nest site will be best, and humans can do the same thing, even in the face of exceptionally complex decisions." Investors in the stock market, scientists on a research project, even kids at a county fair guessing the number of beans in a jar can be smart groups, he says, if their members are diverse, independent minded, and use a mechanism such as voting, auctioning, or averaging to reach a collective decision.

Take bettors at a horse race. Why are they so accurate at predicting the outcome of a race? At the moment the horses leave the starting gate, the odds posted on the pari-mutuel board, which are calculated from all bets put down, almost always predict the race's outcome: Horses with the lowest odds normally finish first, those with second lowest odds finish second, and so on. The reason, Surowiecki says, is that pari-mutuel betting is a nearly perfect machine for tapping into the wisdom of the crowd.

"If you ever go to the track, you find a really diverse group, experts who spend all day perusing daily race forms, people who know something about some kinds of horses, and others who are betting at random, like the woman who only likes black horses," he says. Like bees trying to make a decision, bettors gather all kinds of information, disagree with one another, and distill their collective judgment when they place their bets.

That's why it's so rare to win on a long shot.

THERE'S A SMALL PARK near the White House in Washington, D.C., where I like to watch flocks of pigeons swirl over the traffic and trees. Sooner or later, the birds come to rest on ledges of buildings surrounding the park. Then something disrupts them, and they're off again in synchronized flight.

The birds don't have a leader. No pigeon is telling the others what to do. Instead, they're each paying close attention to the pigeons next to them, each bird following simple rules as they wheel across the sky. These rules add up to another kind of swarm intelligence—one that has less to do with making decisions than with precisely coordinating movement.

Craig Reynolds, a computer graphics researcher, was curious about what these rules might be. So in 1986 he created a deceptively simple steering program called boids. In this simulation, generic birdlike objects, or boids, were each given three instructions: 1) avoid crowding nearby boids, 2) fly in the average direction of nearby boids, and 3) stay close to nearby boids. The



A team of inch-long robots spreads out through a mock-up of a turbine engine in a Swiss lab. To speed the task of inspecting each blade, these experimental units can signal neighbors through infrared sensors.

result, when set in motion on a computer screen, was a convincing simulation of flocking, including lifelike and unpredictable movements.

At the time, Reynolds was looking for ways to depict animals realistically in TV shows and films. (*Batman Returns* in 1992 was the first movie to use his approach, portraying a swarm of bats and an army of penguins.) Today he works at Sony doing research for games, such as an algorithm that simulates in real time as many as 15,000 interacting birds, fish, or people.

By demonstrating the power of self-organizing models to mimic swarm behavior, Reynolds was also blazing the trail for robotics engineers. A team of robots that could coordinate its actions like a flock of birds could offer significant advantages over a solitary robot. Spread out over a large area, a group could function as a powerful mobile sensor net, gathering information about what's out there. If the group encountered something unexpected, it could adjust and respond quickly, even if the robots in the group weren't very sophisticated, just as ants are able to come up with various options by trial and error. If one member of the group were to break down, others could take its place. And, most important, control of the group could be decentralized, not dependent on a leader.

"In biology, if you look at groups with large numbers, there are very few examples where you have a central agent," says Vijay Kumar, a professor of mechanical engineering at the University of Pennsylvania. "Everything is very distributed: They don't all talk to each other. They act on local information. And they're all anonymous. I don't care who moves the chair, as long as somebody moves the chair. To go from one robot to multiple robots, you need all three of those ideas."

Within five years Kumar hopes to put a networked team of robotic vehicles in the field. One purpose might be as first responders. "Let's say there's a 911 call," he says. "The fire alarm goes off. You don't want humans to respond. You want machines to respond, to tell you what's happening. Before you send firemen into a burning building, why not send in a group of robots?"

Taking this idea one step further, Marco Dorigo's group in Brussels is leading a European effort to create a "swarmanoid," a group of cooperating robots with complementary abilities: "foot-bots" to transport things on the ground, "hand-bots" to climb walls and manipulate objects, and "eye-bots" to fly around, providing information to the other units.

PETER ESSICK

Teams of robots might someday be sent into a village to flush out terrorists.

The military is eager to acquire similar capabilities. On January 20, 2004, researchers released a swarm of 66 pint-size robots into an empty office building at Fort A. P. Hill, a training center near Fredericksburg, Virginia. The mission: Find targets hidden in the building.

Zipping down the main hallway, the foot-long red robots pivoted this way and that on their three wheels, resembling nothing so much as large insects. Eight sonars on each unit helped them avoid collisions with walls and other robots. As they spread out, entering one room after another, each robot searched for objects of interest with a small, Web-style camera. When one robot encountered another, it used wireless network gear to exchange information. ("Hey, I've already explored that part of the building. Look somewhere else.")

In the back of one room, a robot spotted something suspicious: a pink ball in an open closet (the swarm had been trained to look for anything pink). The robot froze, sending an image to its human supervisor. Soon several more robots arrived to form a perimeter around the pink intruder. Within half an hour, all six of the hidden objects had been found. The research team conducting the experiment declared the run a success. Then they started a new test.

The demonstration was part of the Centibots project, an investigation to see if as many as a hundred robots could collaborate on a mission. If they could, teams of robots might someday be sent into a hostile village to flush out terrorists or locate prisoners; into an earthquake-damaged building to find victims; onto chemical-spill sites to examine hazardous waste; or along borders to watch for intruders. Military agencies such as DARPA (Defense Advanced Research Projects Agency) have funded a number of robotics programs using collaborative flocks of helicopters and fixed-wing aircraft, schools of torpedo-shaped underwater gliders, and herds of unmanned ground vehicles. But at the time, this was the largest swarm of robots ever tested.

"When we started Centibots, we were all thinking, this is a crazy idea, it's impossible to do," says Régis Vincent, a researcher at SRI International in Menlo Park, California. "Now we're looking to see if we can do it with a thousand robots."

IN NATURE, OF COURSE, animals travel in even larger numbers. That's because, as members of a big group, whether it's a flock, school, or herd, individuals increase their chances of detecting predators, finding food, locating a mate, or following a migration route. For these animals, coordinating their movements with one another can be a matter of life or death.

"It's much harder for a predator to avoid being spotted by a thousand fish than it is to avoid being spotted by one," says Daniel Grünbaum, a biologist at the University of Washington. "News that a predator is approaching spreads quickly through a school because fish sense from their neighbors that something's going on."

When a predator strikes a school of fish, the group is capable of scattering in patterns that make it almost impossible to track any individual. It might explode in a flash, create a kind of moving bubble around the predator, or fracture into multiple blobs, before coming back together and swimming away.

Animals on land do much the same, as Karsten Heuer, a wildlife biologist, observed in 2003, when he and his wife, Leanne Allison, followed the vast Porcupine caribou herd *(Rangifer tarandus granti)* for five months. Traveling more than a thousand miles with the animals, they documented the migration from winter range in Canada's northern Yukon Territory to calving grounds in Alaska's Arctic National Wildlife Refuge.

"It's difficult to describe in words, but when the herd was on the move it looked very much like a cloud shadow passing over the landscape, or a mass of dominoes toppling over at the same time and changing direction," Karsten says. "It was as though every animal knew what its neighbor was going to do, and the neighbor beside that and beside that. There was no anticipation or reaction. No cause and effect. It just was."

One day, as the herd funneled through a gully at the tree line, *(Continued on page 146)*

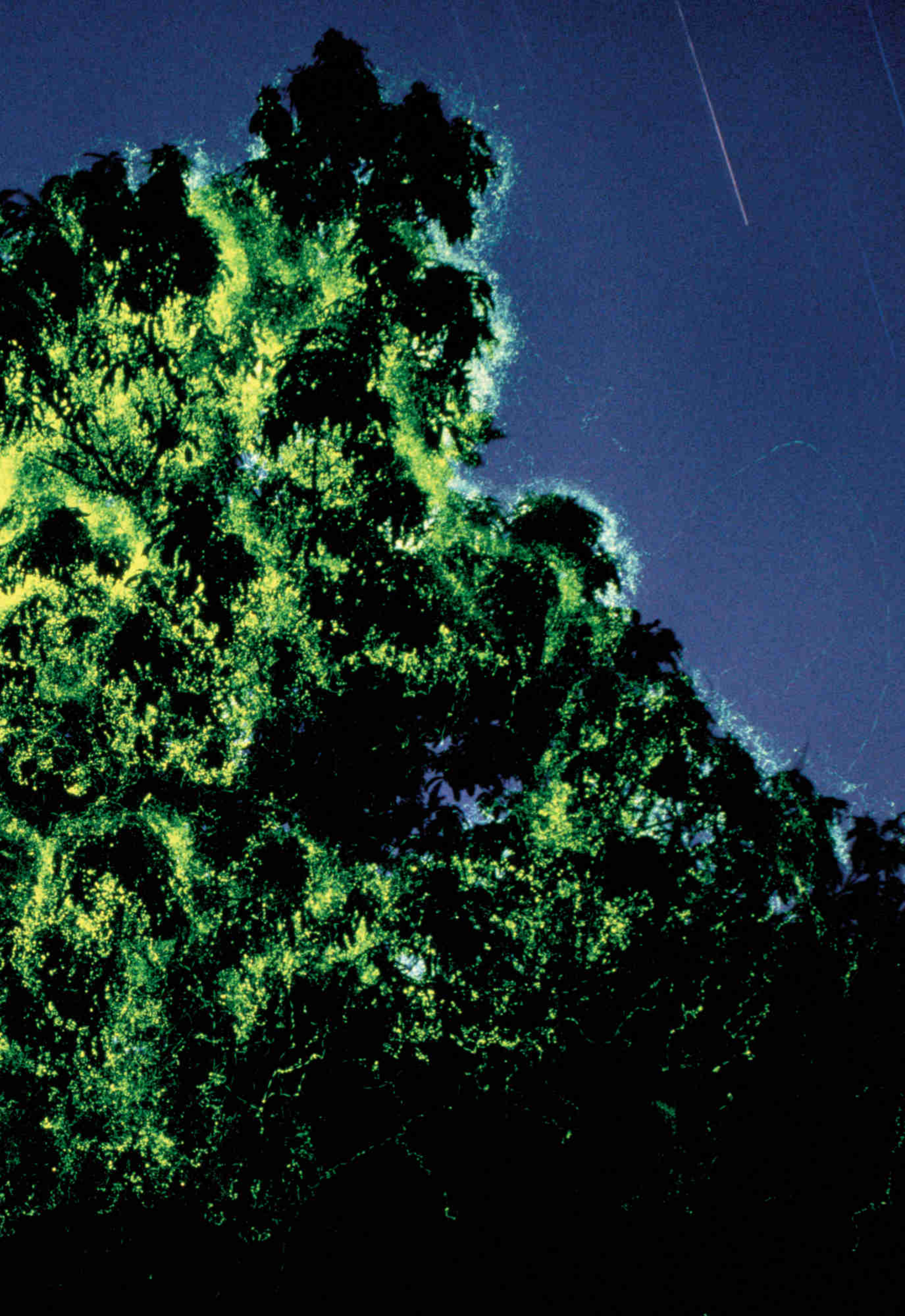
A red color ring means "grab me," a blue one "stay away," as robots in a Brussels lab converge to form a single unit. Their goal: to accomplish something together they can't do alone, such as moving a heavy object.

NATIONAL GEOGRAPHIC PHOTOGRAPHER MARK THIESSEN



A tree ablaze with fireflies in Indonesia blinks on and off as each insect adjusts its flashes to match the others. Such self-organized behavior resembles the synchronized firing of heart muscle cells or the rhythmic applause of a crowd—but seems more mysterious.

MITSUHIKO IMAMORI, MINDEN PICTURES



Every caribou knew when it was time to run, even if didn't know exactly why.

Karsten and Leanne spotted a wolf creeping up. The herd responded with a classic swarm defense.

"As soon as the wolf got within a certain distance of the caribou, the herd's alertness just skyrocketed," Karsten says. "Now there was no movement. Every animal just stopped, completely vigilant and watching." A hundred yards closer, and the wolf crossed another threshold. "The nearest caribou turned and ran, and that response moved like a wave through the entire herd until they were all running. Reaction times shifted into another realm. Animals closest to the wolf at the back end of the herd looked like a blanket unraveling and tattering, which, from the wolf's perspective, must have been extremely confusing." The wolf chased one caribou after another, losing ground with each change of target. In the end, the herd escaped over the ridge, and the wolf was left panting and gulping snow.

For each caribou, the stakes couldn't have been higher, yet the herd's evasive maneuvers displayed not panic but precision. (Imagine the chaos if a hungry wolf were released into a crowd of people.) Every caribou knew when it was time to run and in which direction to go, even if it didn't know exactly why. No leader was responsible for coordinating the rest of the herd. Instead each animal was following simple rules evolved over thousands of years of wolf attacks.

That's the wonderful appeal of swarm intelligence. Whether we're talking about ants, bees, pigeons, or caribou, the ingredients of smart group behavior—decentralized control, response to local cues, simple rules of thumb—add up to a shrewd strategy to cope with complexity.

"We don't even know yet what else we can do with this," says Eric Bonabeau, a complexity theorist and the chief scientist at Icosystem Corporation in Cambridge, Massachusetts. "We're not used to solving decentralized problems in a decentralized way. We can't control an emergent phenomenon like traffic by putting stop signs and lights everywhere. But the idea of shaping traffic as a self-organizing system, that's very exciting."

Social and political groups have already adopted crude swarm tactics. During mass protests eight years ago in Seattle, anti-globalization activists used mobile communications devices to spread news quickly about police movements, turning an otherwise unruly crowd into a "smart mob" that was able to disperse and re-form like a school of fish.

The biggest changes may be on the Internet. Consider the way Google uses group smarts to find what you're looking for. When you type in a search query, Google surveys billions of Web pages on its index servers to identify the most relevant ones. It then ranks them by the number of pages that link to them, counting links as votes (the most popular sites get weighted votes, since they're more likely to be reliable). The pages that receive the most votes are listed first in the search results. In this way, Google says, it "uses the collective intelligence of the Web to determine a page's importance."

Wikipedia, a free collaborative encyclopedia, has also proved to be a big success, with millions of articles in more than 200 languages about everything under the sun, each of which can be contributed by anyone or edited by anyone. "It's now possible for huge numbers of people to think together in ways we never imagined a few decades ago," says Thomas Malone of MIT's new Center for Collective Intelligence. "No single person knows everything that's needed to deal with problems we face as a society, such as health care or climate change, but collectively we know far more than we've been able to tap so far."

Such thoughts underline an important truth about collective intelligence: Crowds tend to be wise only if individual members act responsibly and make their own decisions. A group won't be smart if its members imitate one another, slavishly follow fads, or wait for someone to tell them what to do. When a group is being intelligent, whether it's made up of ants or attorneys, it relies on its members to do their own part. For those of us who sometimes wonder if it's really

Running With the Herd See images of swarm behavior in nature and more in our Photo Gallery at **ngm.com/0707**.



worth recycling that extra bottle to lighten our impact on the planet, the bottom line is that our actions matter, even if we don't see how.

Think about a honeybee as she walks around inside the hive. If a cold wind hits the hive, she'll shiver to generate heat and, in the process, help to warm the nearby brood. She has no idea that hundreds of workers in other parts of the hive are doing the same thing at the same time to the benefit of the next generation.

"A honeybee never sees the big picture any more than you or I do," says Thomas Seeley, the bee expert. "None of us knows what society as a whole needs, but we look around and say, oh, they need someone to volunteer at school, or mow the church lawn, or help in a political campaign."

If you're looking for a role model in a world of complexity, you could do worse than to imitate a bee. □

Locusts beyond number rise in a single black cloud in Mauritania, devouring every crop in their path and leaving hunger or starvation in their wake. Finding ways to prevent such plagues depends on a deeper understanding of swarm theory and the surprising ways it affects our lives.

HOW TO HELP



Vunel Kasachi comforts her ten-month-old son, Nicholas, a malaria patient at Kalene Mission Hospital in Zambia.

BEDLAM IN THE BLOOD, PAGE 32

Net Gains

Insecticide-treated bed nets may be low-tech, but they are a highly effective way to prevent the spread of malaria. According to the U.S. Centers for Disease Control and Prevention, widespread use of treated bed nets has been shown to reduce transmission of the disease by about 90 percent. But the nets—which cost several dollars each—may be difficult to come by or too costly for those who need them most. Reapplication of pyrethroid insecticide at the recommended intervals of 6 to 12 months can also pose problems with older nets. The following groups help make treated nets available in high-risk areas and educate people about their proper use.

- **Against Malaria** programs send bed nets to communities in Africa, Asia, and the Americas. Track the progress of the donated nets, from their manufacture to their delivery, at *againstmalaria.com/netdelivery.*

- **Centers for Disease Control Foundation** helps CDC scientists distribute bed nets and address other health needs for people in sub-Saharan African countries. *cdcfoundation.org/bednets*

- **Population Services International** annually delivers millions of nets, insecticide kits, and malarial treatments to more than 30 countries in Africa, Asia, and South America. This nonprofit is one of the largest distributors of insecticide-treated nets in the world. *psi.org/malaria*

- **Malaria No More** supports net distribution, education, mosquito spraying, and antimalarial drugs in Africa. *malarianomore.org*

PHOTO: JOHN STANMEYER

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John Stanmeyer wades a flooded Kolkata street.

ON ASSIGNMENT **Immersed in the Story** At the tail end of monsoon season, photographer John Stanmeyer made his way to Kolkata, India, looking for water. The annual storms usually flood much of the city, and the standing water provides a vast breeding ground for malaria-carrying mosquitoes. But a hot sun baked the city for two weeks straight. Not a drop fell. The day before his flight home, it finally poured, and Stanmeyer was able to wade through the streets. The sewage-filled water "was disgusting, but you don't really think about that," he says. "You just think to yourself that this is the best way to deliver the story to readers so that they can fully understand urban malaria. I wanted them to feel it."



Undulambia lindbladi

BEHIND THE SCENES **Lindblad's Moth** Lindblad Expeditions, the travel company founded by Sven-Olof Lindblad in 1979, brings some 5,000 visitors to the Galápagos Islands each year and actively supports local sustainability projects. To honor Lindblad's work, lepidopterist Bernard Landry—in association with the Charles Darwin Foundation—named a new Galápagos moth species he discovered after Lindblad: *Undulambia lindbladi* (left). And National Geographic appointed Lindblad to its Conservation Trust Advisory Board, which awards grants worldwide. "Sven pioneered tourism as a vehicle for conservation," says John Francis, vice president for research, conservation, and exploration. "His appointment reflects our interest in geotourism."

PHOTOS: AC ROY (TOP); B. LANDRY, MUSÉUM D'HISTOIRE NATURELLE, GENEVA



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INSIDE GEOGRAPHIC



On the first day of National Geographic photo camp in a Ugandan refugee camp, children get acquainted with a digital camera.

NG EXHIBITS

Uganda Photo Camp

For a week last November, children at a refugee camp in western Uganda were able to document their own lives while learning the basics of light, composition, and camera mechanics from photographers Ed Kashi, Reza, Chris Rainier, and Neo Ntsoma. Many of the young participants have spent their entire lives as refugees. This year ten more photo camps in Mexico and the U.S. will focus on refugees and immigrant communities, giving children a chance to tell their stories through pictures. The Uganda campers' photographs are on display now through September 3 at the National Geographic Society headquarters in Washington, D.C.

July Contributors

MALARIA, page 32

Michael Finkel stayed healthy on assignment for this month's malaria piece, but he caught a severe case of the disease in northern Thailand in 2002. He is the author of *True Story.*

John Stanmeyer, a founding member of the photo agency VII, has spent the past three years working on a photographic study of Balinese spirituality and mysticism.

ICEMAN, page 68

Stephen S. Hall's most recent book, *Size Matters,* is about the biological, psychological, and cultural aspects of male human growth.

Kazuhiko Sano is an award-winning illustrator who teaches at the Academy of Art University in San Francisco, California.

BIRDS OF PARADISE, page 82

Jennifer S. Holland is a NATIONAL GEOGRAPHIC senior writer who specializes in natural history stories.

Tim Laman, a regular photographic contributor to the magazine, is a research associate in the ornithology department at Harvard's Museum of Comparative Zoology.

TONGASS NATIONAL FOREST, page 102

Douglas H. Chadwick has written ten books on wildlife. His newest, for children, is *Growing Up Grizzly,* a true tale about an Alaska bear family.

Melissa Farlow's assignment in Alaska's Tongass National Forest, which gets an average of almost 150 inches of rain a year, was the first she'd had in which her cameras had to wear rain gear.

SWARMS, page 126

Peter Miller, a GEOGRAPHIC senior editor, admits a soft spot for honeybees even though he was once chased by killer bees in Mexico.

Tales From the Field Learn more about our contributors in Features at **ngm.com/0707.**

PHOTO: ED KASHI

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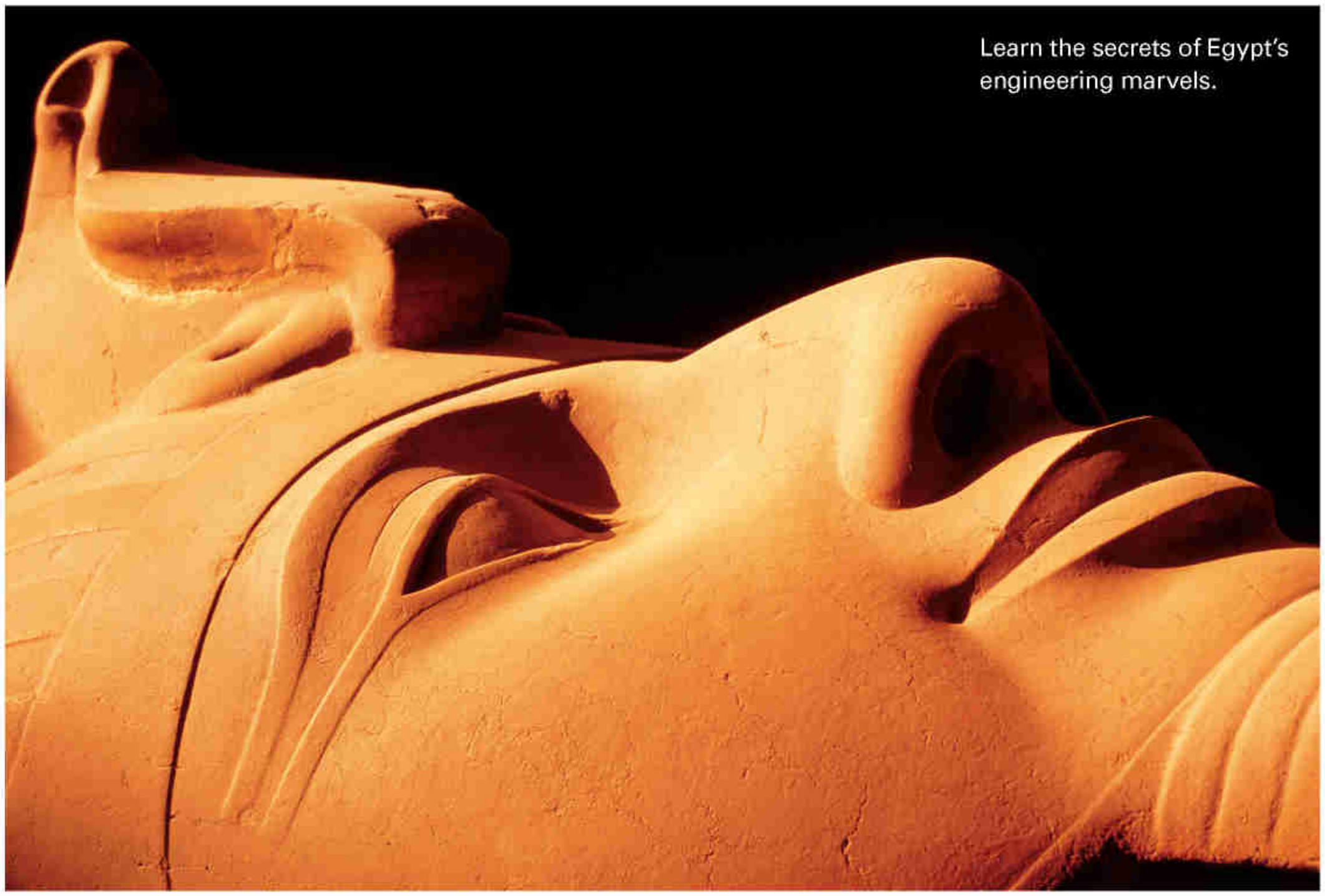
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Photograph by Reza

INSIDE GEOGRAPHIC



NATIONAL GEOGRAPHIC CHANNEL

Engineering Egypt Travel back more than 4,000 years to a time when laborers along the Nile laid a foundation for spectacular feats of engineering that have lasted millennia. Using advanced computer imaging, National Geographic Channel unlocks the technology that built the Great Pyramid at Giza, one of the largest stone structures ever erected, as well as the rock-cut temples at Abu Simbel, constructed during the reign of the pharaoh Ramses II (statue above). This month, watch Egypt evolve, block by block, to architectural glory.

NG Partners

The Green Guide The profusion of "natural" cleaning products on the market can flummox even the savviest of eco-minded shoppers. Then there's the puzzle of what fish is OK to eat or whether growing a green lawn is ecologically responsible. Fortunately, help is here. The National Geographic Society has acquired *The Green Guide,* a comprehensive website and bimonthly newsletter for consumers that is packed with tips on how to live a healthier life while treading lightly on Earth's resources. In addition to articles on the latest eco-news, each issue includes a shopping guide (or PDA download from the website below) with ideas for transforming your house into an Earth-friendly haven. Check it out at *thegreenguide.com.*



National Public Radio This summer, as part of an extended collaboration with the National Geographic Society, NPR will feature tales of our warming planet on *Climate Connections.* Some upcoming programs in the radio series include a surprisingly successful tree planting project in Niger, the story of Mali nomads who have stopped roaming to better weather an unpredictable climate, and possible changes in Switzerland's cheese if alpine flowers that once flavored cows' milk won't thrive where they used to. Go to *ngm.com/climateconnections* and *npr.org/climateconnections* to learn more.

PHOTO: CHRISTOPHE BOISVIEUX, CORBIS



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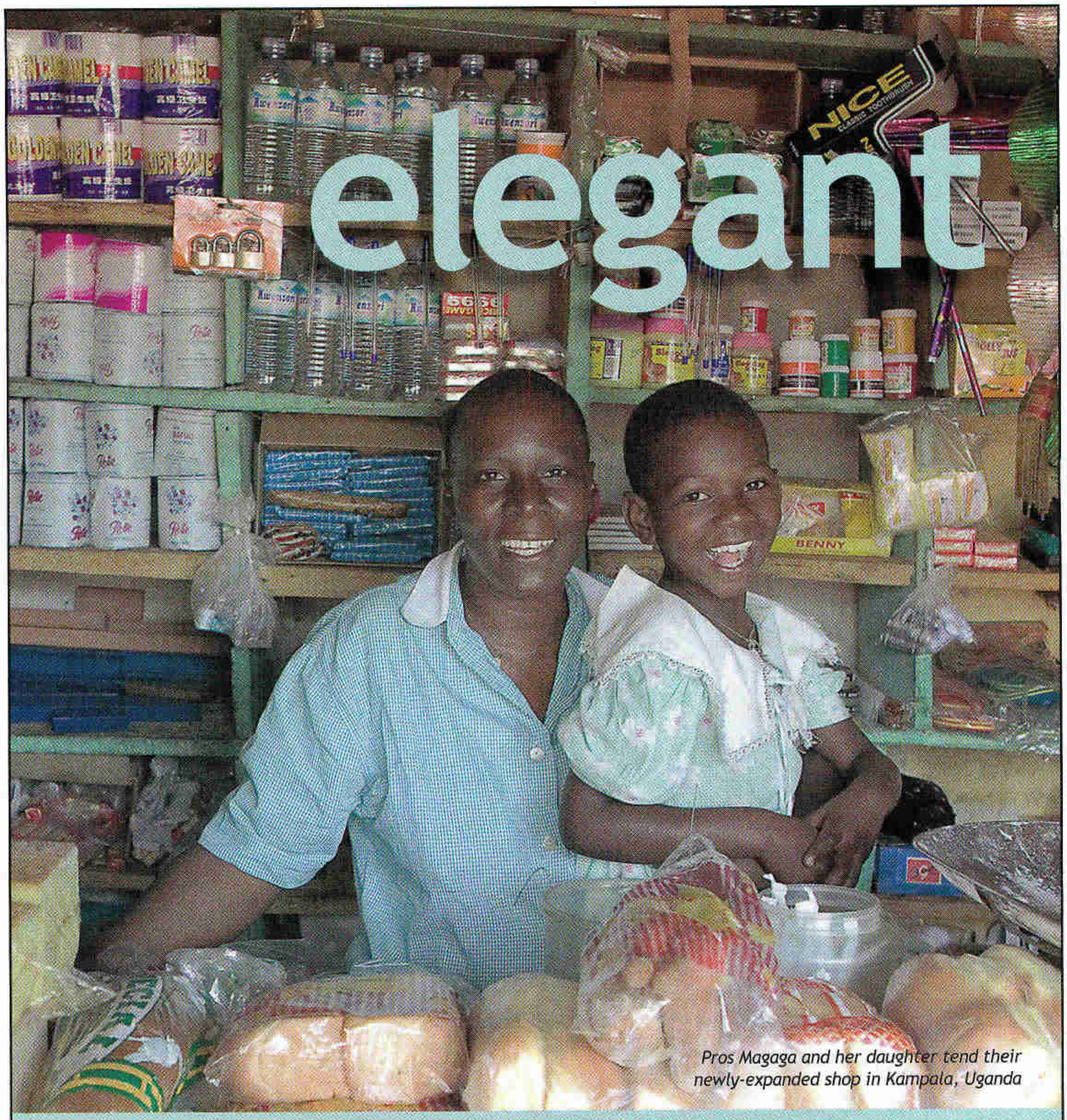
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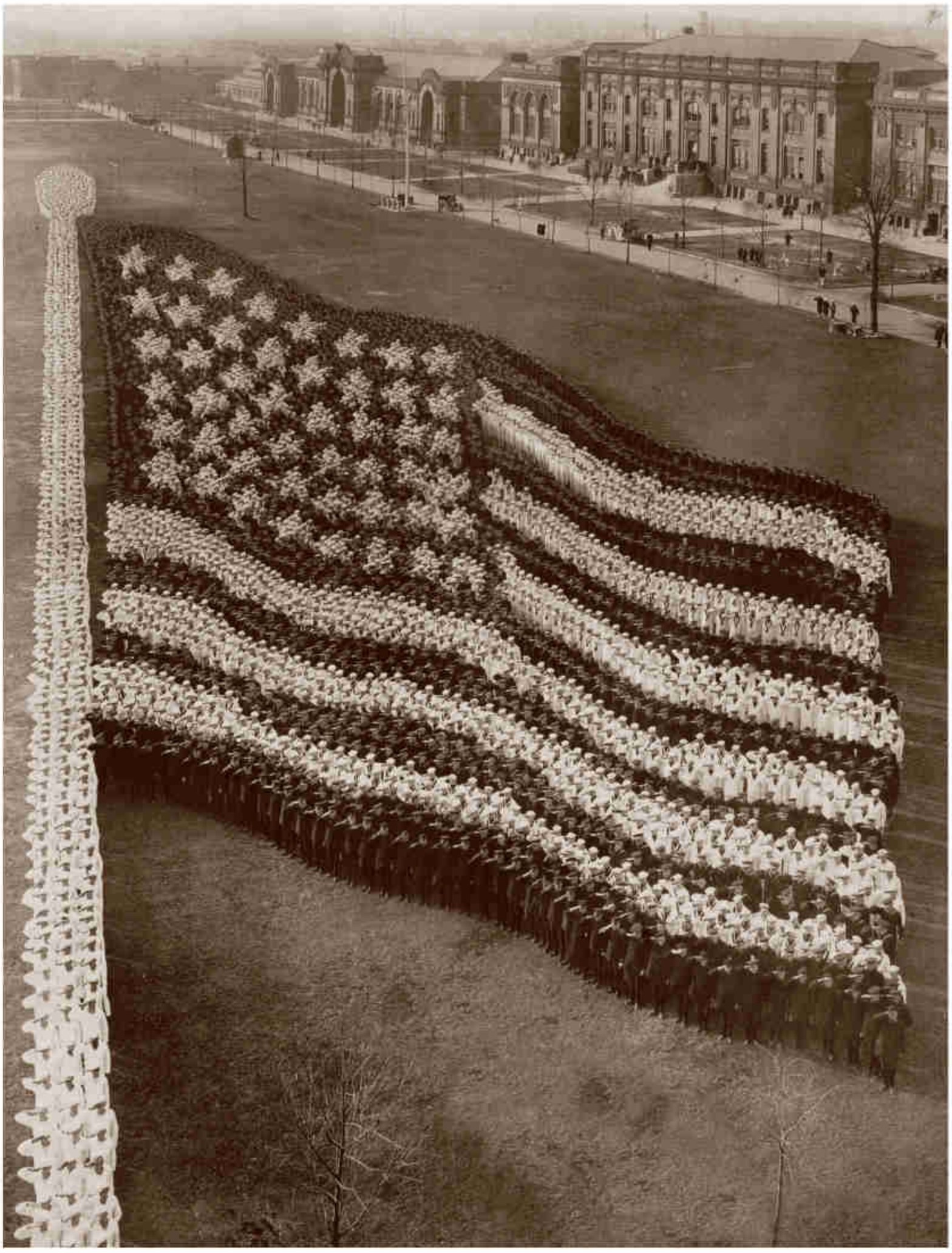


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FLASHBACK



Flag Wavers Far from the ocean, 10,000 sailors-to-be took the form of a flag at Illinois's Great Lakes Naval Training Station. The photo ran in March 1918 with a story by former President William Howard Taft, who emphasized the importance of the salute in his lectures to young World War I draftees. "The freedom and independence that an American youth enjoys make it necessary to have the reason for such a ceremony explained to him," Taft wrote. "His self-confidence and his self-conceit make it irksome to him, at first, thus to register his subordinate position or to obey implicitly, as he must, if he would be a good soldier." *—Margaret G. Zackowitz*

Flashback Archive Find all the photos plus e-greetings at **ngm.com/0707.**

PHOTO: GREAT LAKES RECRUIT

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